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PART 1.00 – GENERAL

1.01 INTENT

A. General

1. This Specification defines the conditions and requirements applicable to the overhaul of the Authority's F40PH-2C and F40PHM-2C road locomotive units, together with their auxiliary equipment and accessories, and including the transportation to and from the Contractor's facilities.

2. There are a total of thirty-six (36) locomotives, identified by road numbers 1050-1072 and 1074-1075, which were built by the Electro-Motive Division of General Motors Corp. as follows. Twelve (12) additional locomotives, identified by unit numbers 1025-1036 were built by Morrison Knudsen:

   a. Units 1050-1075[1] overhauled in 1999-2003

   b. Units 1025-1036 overhauled in 2003-2004

3. Each locomotive incorporates:

   a. Prime Mover: EMD 16-645E3C, 3000 hp.

   b. Main Generator: AR10-D14, AR10-D18 or AR10-CA5.

   c. Head End Power (HEP): Caterpillar 3412, independent diesel engine capable of 600 kw output at 480 VAC 60 Hz.

4. The locomotives presently MU with all coaches and locomotives in the Authority's existing commuter rail fleet. This compatibility shall be maintained for all MBTA locomotives and coaches.

5. It is the Authority's intent that these locomotives shall be completely overhauled basically in-kind with appropriate and necessary enhancements and any modifications described in these specifications, but not be remanufactured as the term is defined by the FRA in 49 CFR 229.5.

   a. The Contractor is responsible for delivering locomotives meeting that requirement and verifying that previously used components comprise over 25% of all the components used in their construction, calculated in accordance with that regulation.

   b. The locomotives shall also be delivered with certification of compliance with Tier 0+ exhaust emission standards as required by 40 CFR 1033.1(c) and 40 CFR 1033.101.

6. The locomotives after overhaul shall be capable of providing a minimum of ten (10) years reliable service, averaging 100,000 miles of service each year, without need of major overhaul or restoration.

   a. The locomotives shall be repaired to a condition such that no significant rework

[1] Unit 1073 scrapped

would be required for another 20 years of reliable service, assuming that appropriate major component overhaul activities are performed within that service life.

7. The Contractor shall be responsible for:

    a. All engineering effort required to effect the overhaul of the locomotives, including all required upgrading and modification.

    b. Procurement of all parts, materials and supplies required to effect the overhaul of the locomotives.

    c. All labor, tools, equipment and facilities required for the overhaul program.

    d. All documentation of work performed including all hardware and software version/revision baseline documentation.

    e. Transportation of locomotives to Contractor's facility from an MBTA facility or location within 100 miles of Boston and the return transportation of those locomotives to an MBTA-designated facility after completion of their overhaul.

8. After overhaul pursuant to this Specification, the locomotives shall be:

    a. Complete with auxiliary equipment and accessories

    b. In full working order, including all sub-systems.

    c. Identical to each other in configuration and all details.

9. Components used in the locomotives shall be operationally compatible with those on the Authority's existing locomotives.

10. The overhaul of major components shall be in accordance with the original equipment manufacturer (OEM) recommendations and maintenance instructions, subject to Engineer acceptance.

11. Replacement parts for major components, including main engine, generator, and auxiliary generator, head end power (HEP) engine generator, traction motors, and air compressor shall be OEM, or a service proven equivalent as approved by the Engineer.

    a. The Authority requires that all parts supplied or overhauled meet the requirements of the OEM of the locomotives in terms of durability, tolerances, and fitness of purpose.

    b. The Authority does not require that parts supplied be purchased from the original manufacturer, but does require that the parts meet OEM standards and be service proven in an operating environment comparable to that of the MBTA.

    c. It is the responsibility of the Contractor to provide proof that the parts supplied meet OEM standards, to the approval of the Authority.

12. Where components or assemblies are specified to be overhauled or remanufactured, the Contractor may at his discretion supply new material at no additional cost to the

Authority.

13. All consumables such as filters, gaskets, brake shoes, diodes, fuses, brushes, etc., shall be replaced with new.

14. All small hardware and body parts which are missing shall be replaced with new material.

15. All steps, grab irons, and other safety appliances must comply with current Federal Railroad Administration requirements.

16. See also Part 23.03 - Clearance Diagram.

1.02 BASIC DESIGN CONSIDERATIONS AND MAINTAINABILITY

A. General

1. The overhaul and modification of the locomotives shall make every possible provision for safety of employees, for maximum ease and safety of passage through the locomotive, and for ease of cleaning and maintaining.

B. Basic requirements

1. Apparatus requiring frequent inspection or attention shall be readily accessible and replaceable.

a. Apparatus supports and housings shall be arranged so that apparatus may be mounted interchangeably to the greatest extent possible.

2. As part of a general requirement for safe construction the Contractor shall ensure that there shall be no sharp edges or corners any place in the locomotive where operators or maintenance personnel may come in contact with such edges.

a. This requirement shall apply to equipment or components furnished by suppliers as well as the Contractor's own manufacture or repair.

C. Maintainability of the locomotive and associated equipment shall be given prime consideration by the Contractor in the overhaul of the locomotive, and by the Contractor and his vendors in the design and building or overhaul of the individual subsystems.

D. No component of the locomotive, excluding the head end power engine system shall require scheduled periodic maintenance any more frequently than once every ninety-two (92) days, normal daily inspections and servicing excluded. If the option for upgrade of the HEP system to meet EPA Tier 2 requirements is exercised, the HEP shall have the service interval increased as delineated in **Appendix E**.

1.03 DELIVERY

A. Delivery of Locomotives to the Authority.

1. The Contractor bears full responsibility for all related costs for the transport of the Locomotives, Spares, Training Aids, and related equipment as specified to the

Authority's designated destination.

2. The Offeror shall submit with the proposal a detailed schedule for the design, manufacture, testing and delivery of each locomotive in the form of a milestone type bar chart. Each chart shall indicate anticipated dates for starting and completing all major aspects of the program including, but not limited to, First Article Inspection and completion of major hardware components; the delivery to the MBTA of the Pilot Locomotive(s); and subsequent delivery of the balance of the Locomotives on order. Quantity to be delivered shall be clearly noted.

3. The Locomotives shall be shipped so as to be received by the Authority at the rate of one (1) Locomotives a month. Hours/Days of delivery shall be approved by the Authority.

4. Vehicles shall be delivered in accordance with the delivery schedule upon certification by the Engineer's authorized representative that all testing specified in these Specifications has been completed.

5. The Pilot Locomotive(s) shall be completed at the Contractor's facility for the Authority's inspection, review and approval for production fleet release. **Delivery of the Pilot Locomotive to the Authority shall be no later than ten (10) months from Notice to Proceed**.

6. Upon Conditional Acceptance of the Pilot Locomotive, **delivery of the production fleet shall commence at the rate of one (1) locomotive per month, starting 12 months from Notice to Proceed**. Should the Contractor be prepared to ship additional units, the Contractor shall request approval to ship 30 days in advance of proposed ship date in writing for MBTA approval.

    a. Failure to meet the delivery schedule for the Pilot Locomotive and all Production Locomotives, will result in Liquidated Damages as specified in the Commercial Terms Section 7.1 of this RFP package.

7. After shipment, each complete locomotive shall be received on its own wheels and in a ready-to-test condition at the MBTA designated location. Each locomotive shall then be examined jointly by representatives of the Authority and the Contractor. The Authority shall then issue a "Receiving Notice" to the Contractor which shall acknowledge receipt of the vehicle and furnish appropriate notation as to its apparent "as received" condition. The "Receiving Notice" shall describe any missing parts or damage that may have occurred during shipment. The "Receiving Notice" shall be signed by the Authority's representative and the Contractor's representative to attest to the stated condition of the vehicle.

    NOTE: The Contractor must advise the Authority five (5) days prior to anticipated delivery to the MBTA designated location, of each vehicle

8. During the test period for the Pilot Locomotive, the Contractor may continue work on other Locomotives at its own risk, but no additional Locomotives shall be shipped to the Authority until the approval of the Pilot Locomotive for production release.

9. The Contractor shall assume the cost of all repairs and defective component replacement (including labor) until the vehicles are accepted by the Authority at the Authority's acceptance site or at a location as designated by the Authority.

1.04 STANDARDS

A. The equipment and materials provided by the Contractor shall comply specifically with the requirements of the AAR and FRA and all applicable state and local codes in effect at the time of submission of Proposal by the Contractor.

B. If a conflict is discovered among any of the above requirements the following order of priority shall govern:

1. FRA - USDOT

2. Laws of the Commonwealth of Massachusetts

3. Purchase agreement and Specification

4. Recommendations of the AAR

C. In the event of such conflict, the Contractor shall notify the Authority promptly.

D. Trade names and/or manufacturer's names and part numbers shown through this specification are not "Sole Source Item" unless specifically identified as such.

1. The items indicated are now in use on the Authority's Commuter Rail rolling stock and have successfully met operating requirements of reliability, maintainability, life expectancy, and interchangeability.

2. These items are stocked for normal maintenance and repair procedures.

E. The Contractor may, at his option, recommend alternates for the Authority's acceptance in accordance with Part C7.9.3.

F. Where references are made to the requirements of the FRA (49 CFR), recommendations of the AAR, and specifications and instructions of the equipment manufacturer, it is the intent that they shall be the latest issue in effect at the time of Proposal submittal.

1.05 DIMENSIONS

A. Major dimensions of the Authority's class F40PH-2C locomotives as built:

1. Distance over coupler pulling faces: 64 ft. 3 in. (19.6m)

2. Distance between bolster centers: 33 ft. (10.06 m)

3. Truck wheel base: 9 ft. 0 in. (2.74m)

4. Height: 15 ft. 4-7/8 in. (4.572 m)

5. Width over handrails and vents: 10 ft. 8.75 in. (3.27 m)

6. Curve negotiation capability:

a. 174 ft. (53 m) Radius - 33 degree curve: Represents a single unit curve negotiation as limited by truck swing.

b. 222 ft. (68 m) Radius - 26 degree curve: Represents two similar units coupled in multiple limited by coupler swing and equipped with type "F" couplers.

c. 255 ft. (78 m) Radius - 20 degree curve: Represents minimum curve capability of an F40PH-2C coupled to an MBTA 85 ft. 4 in. passenger car equipped with type H couplers limited by car coupler swing.

d. The F40PH-2C coupled to an MBTA 85 ft. 4 in. passenger car, limited by jumper cables will negotiate a number 8 Boston and Maine crossover on 12 ft. 2 in. track centers (Figure A11).

7. Diameter of wheels: 40 in. (1.02m)

8. Gearing: 57 : 20

B. Weights and supplies

1. Total loaded weight on rails as built (nominal): 279,000 - 283,500 lbs

2. Fuel capacity: 2,000 gallons (7,571 liters)

3. Lubricating oil capacity: 243 gallons (920 liters)

4. Cooling system capacity: 254 gallons (962 liters)

5. Sand capacity: 49 cubic ft. (1.39 cubic m)

1.06 ENVIRONMENT AND WAYSIDE CONDITIONS

A. Vehicle shall be designed to operate in the following ambient conditions, which shall be assumed to represent those in Boston:

1. Temperatures

	Normal	Peak
Maximum:	98°F (37°C)	104° F (40°C)
Minimum:	0°F (-18°C)	-18°F (-28°C)

a. The locomotives shall be capable of continuous operation at the engine manufacturer's full rated horsepower at AAR standard conditions. Engine lube oil, cooling and exhaust systems and locomotive electrical equipment design shall ensure that the locomotive is capable of continuously delivering the full available horsepower of the diesel engines to traction and HEP at ambient temperatures of up to 111 deg. F, recognizing that there may be some derating above 104 deg F (40 deg C).

2. Wind Velocity

a. Normal maximum 40 mph (64 kmph) with gusts to 87 mph (140 kmph).

3. Relative Humidity

a. 20% to 100% (Non-Condensing).

4. Snow

a. Maximum of 23.6" (599 mm) per 24 hour period.

5. Rain Fall

a. 2.10" (53 mm) in any one hour, with a maximum of 8.40" (213 mm) per 24 hour period.

6. Freezing Rain

a. 0.50" (12.7 mm) in any hour, with a maximum of 2.00" (51 mm) per day.

7. Latitude

a. 42° 21' north

8. Altitude

a. 15 to 600 feet (4.6 to 182 meters) above mean sea level, concurrent with maximum temperature requirements.

B. Equipment Temperature Considerations

1. All equipment shall be designed to operate effectively, up to an operating temperature of 130 deg F (55 deg C).

a. Equipment enclosures shall be ventilated if necessary to prevent the internal temperature from exceeding 120°F (49°C) given the environmental conditions in Part 1.06A.

b. The Authority will consider alternatives to this requirement given component location within the locomotive.

2. All equipment shall be designed to withstand extended storage in extreme temperature conditions (non-functioning), from -30°F (-35°C) up to 180°F (82°C)

1.07 GENERAL OVERHAUL REQUIREMENTS

A. This Specification outlines the specific areas of the locomotive in which work is required for renewal, upgrading, overhaul, or replacement of parts or apparatus.

1. It also describes the degree of overhaul and modifications required.

2. The Electro-Motive Division of General Motors (EMD) Maintenance Instructions (M.I.s) incorporated into the text throughout the Specification are not overhaul specifications, but

are guidelines prepared by EMD for the maintenance of the equipment by the user.

3. The M.I.s have been referenced to assist the Contractor in understanding the procedures for disassembly, inspection disassembly, inspection, reassembly and the testing of the subject equipment including a listing of special tools, gauges, and fixtures.

    a. It is the Contractors responsibility to obtain and confirm the most recent revision.

B. Replacement of Wire and Cable

1. See Part 12.10.

C. Replacement of parts or apparatus shall be made in kind except where specified that an upgraded replacement is required.

1. To reduce out of service time, the Contractor may propose unit exchange (UTEX) parts of apparatus for equivalent parts of the same manufacture and meeting the requirements of this Specification.

2. Components furnished by a manufacturer that are assembled, housed, and wired into package units at the point of manufacture, shall be tested at the point of manufacture, and a certified test report concerning actual tests made on the components being furnished for this Contract shall be mutually agreed upon between the Contractor and the Authority.

1.08 SCOPE OF MAJOR OVERHAUL WORK

A. The scope of overhaul work includes, but is not limited to, the items listed in this specification and may be reduced or expanded as determined by the condition of each individual locomotive.

1. Where references to specific parts of the Specification are provided, it is for information only, and is not a guarantee that all relevant parts have been referenced. It is the Contractor’s responsibility to perform all work included in this specification.

B. To provide a uniform basis for prospective Contractor's to prepare their proposals the Authority has provided the following information.

1. A list of special conditions applicable to the individual units, such as failures of major components (**Appendix A**).

2. An itemized list (Replacement Items List) showing nominal quantities of materials and/or work to be furnished by the Contractor, and on which the Contractor shall state his costs to furnish more or less of the quantities indicated.

1.09 PRE-SHIPMENT AND RECEIVING INSPECTIONS

A. Pre-Shipment Inspection at Authority-Designated Facility

1. Prior to the movement of each locomotive to the Contractor, it shall be visually inspected to assess its physical condition by representatives of both the Authority and the Contractor.

a. Both representatives shall sign the inspection report.

2. The Pre-Shipment Inspection report shall be forwarded to the Authority and shall be recorded in the Vehicle History Book.

B. Receiving Inspection at Contractor's plant

1. Upon delivery of each locomotive at the Contractor's plant, it shall be visually inspected by the representatives of the Authority, the Contractor, and the Carrier for damage, loss, vandalism, or other discrepancies incurred.

a. A Receiving Inspection Report listing all such damage, loss, vandalism, or other discrepancies shall be signed by the above representatives.

2. The Receiving Inspection report shall be forwarded to the Authority and shall be recorded in the Vehicle History Book.

C. Pre-Shipment Inspection at Contractor’s Plant

1. Prior to the movement of each overhauled locomotive from the Contractor’s plant to the Authority, it shall be visually inspected to assess its physical condition by representatives of both the Authority and the Contractor.

a. Both representatives shall sign the inspection report.

2. The Pre-Shipment Inspection report shall be forwarded to the Authority and shall be recorded in the Vehicle History Book.

D. Receiving Inspection at Authority-Designated Facility

1. Upon delivery of each overhauled locomotive at the Authority-designated location, and before passing into regular operation, each locomotive will be carefully inspected by representatives of the Authority, the Contractor, and the Carrier for damage, loss, vandalism, or other discrepancies incurred. It shall also be inspected by representatives of the Authority, the Contractor for contract compliance.

a. Any part, device, or apparatus requiring adjustment, repair, or replacement will be called to the attention of the Contractor in writing, who shall make adjustment, repair, or replacement at their own expense.

2. A Receiving Inspection Report listing all such damage, loss, vandalism, or other discrepancies shall be signed by the above representatives.

3. The Receiving Inspection report shall be forwarded to the Authority and shall be recorded in the Vehicle History Book.

E. It should be noted that additional changes to the scope of work for each locomotive may be required to accommodate conditions uncovered during the overhaul process.

1. Changes which are determined to be hidden damage as defined in Section C10.4 of the Contract Provisions, shall be addressed in accordance with Section C7.17 Basis of PAyment.

a. The Contractor shall establish his/her labor rate and material mark-up for changes pursuant to this Section and as provided for under Section C10.4 Hidden Damage Allowance.

b. The Contractor shall bring to the immediate attention of the Authority any conditions encountered during the overhaul process which involve hidden damage or missing material, for review and disposition by the Authority.

i. Notification shall be made in writing via email within twenty-four (24) hours, with copy of same to the Authority's resident inspector on-site.

ii. Notification shall be followed by a written statement containing the following information.

(a). A description of the deficiency and details of work to correct same.

(b). Detailed cost data including materials, labor and overhead, and profit.

(c). A statement of additional time, if any, required for completion of the Contract by reason of this change.

2. The Contractor shall not proceed with any work required by the change until written authorization is given by the Engineer.

F. Items to be supplied new shall include, but not be limited to, the following:

1. Pins and bushings (see **Part 4.00**)

2. Traction motor blower bellows assemblies (see Part 2.03 and Appendix C)

3. Coupler carriers (see Part 2.08)

4. No. 2 end draft gear (see Part 2.08)

5. No. 2 end coupler (see Part 2.08)

6. Operator’s cab seat (see Part 3.02)

7. Jump seat (see Part 3.02)

8. Cab heaters (see Part 3.03)

9. Cab ventilators (see Part 3.03)

10. Cab Doors and door seals (see Part 3.06)

11. Weather stripping (see Parts 2.04 and 3.06)

12. Window seals and hardware

13. Windshields and frames (see Part 3.06)

14. Fixed windows (see Part 3.06)

15. Windshields wipers (see Part 3.09)
16. Cab flooring (see Part 3.05)
17. All insulation (see Part 3.04)
18. Pedestal liners and springs (see Part 4.01)
19. Shock absorbers and yaw dampers (see Part 4.01)
20. Wheels (see Part 4.02)
21. Turbo Screen (see Part 5.05 and Appendix D)
22. Fuel pump and motor (see Part 6.05)
23. Battery charger (see Part 8.06)
24. Hoses (see Part 9.04)
25. Integrated Alertness Control System (see Part 10.03)
26. AR10A-D14 main generators - replace with AR10A-CA5 (see **Part 12.01**)
27. Batteries (see Part 12.08)
28. All lamps - upgrade to LED where possible (see Part 15.01)
29. Ditch light controller (see Part 15.01)
30. Ditch lights (see Part 15.01)
31. Radio/public address systems (see Parts 16.01 and 16.02)
32. Electric Hand brake (Part 17.01)
33. Air compressor (see Part 17.05)
34. Air dryer system (see Part 17.05)
35. Electronic bell (see Part 17.08)
36. Exhaust manifold expansion joints (see Appendix D)
37. Exhaust Manifold Heat Shields (see Appendix D)
38. Engine Protection Automatic Drain Valves (see Part 5.03)
39. All pressure switches
40. All air, water, lube oil, and fuel filters & strainers
41. Gaskets, O-rings, and other sealing devices, where components have been disassembled

42. Engine protector (see Appendix D)

G. Items to be overhauled or requalified, as described in these specifications, shall include, but not be limited to the following:

1. Inertial air discharge motors (see Part 2.07)
2. Inertial filter blower and motors (see Part 2.07)
3. Cooling fans (see Part 2.07)
4. Dynamic brake fans (see Part 2.07)
5. Engine cooling water tank (Part 2.07)
6. No. 1 end draft gear (see Part 2.08)
7. No. 1 end coupler (see Part 2.08)
8. Safety appliances (see Part 2.09)
9. Locomotive body corrosion and damage repair (see Part **2.00**)
10. Operating compartment ceiling and side sheets (see Part 3.01)
11. Helper's seat (see Part 3.02)
12. Cab sidewall heaters (see Part 3.03)
13. Control stand (see Part 3.10)
14. Prime mover (see Part **5.00** and **Appendix D**)
15. Traction motor blower unit, including drive (see Part 5.02)
16. Main engine retention tank (see Part 5.07)
17. Exhaust Chamber (see Appendix D)
18. Turbo soak back pump and motor (see Appendix D)
19. Four pass turbo charger after cooler cores (see Appendix D)
20. Fuel tank (see Part 6.01)
21. Layover water pump (see Part 8.04)
22. Layover lube oil pump (see Part 8.04)
23. Traction motors (see Part 12.07and Appendix C)
24. AR10-A-CA5 main generators (see Part 12.01 and Appendix B)

25. Auxiliary generator (see Part 12.03)

26. Battery box (see Part 12.08)

27. MU, HEP, and communications receptacles and jumper cables (see **Part 13.03**)

28. Air brake system, including reservoirs (see Parts 17.01 and 17.07)

29. Exhaust manifold (see Appendix D)

30. Turbocharger (see Appendix D)

31. Journal bearing adapter wear plates (see Parts 4.03 and 4.04)

32. Shutters and operating mechanisms (see Part 12.05)

H. In addition to the above, the following work must be accomplished on all locomotives:

1. Interior and exterior of locomotive cleaned, and repainted per Part **11.00**.

2. Load test prime mover and main generator using separate load box.

3. Load test head-end power unit using separate load box.

4. Prepare locomotive for shipment.

5. Functional road test locomotive with train consist per Part **19.00**.

1.10 CLEARANCE

A. The overhauled locomotive shall comply in all respects, including all projecting appurtenances, with Figure A1, included in **Appendix F**.

1. Under all conditions of manufacturing tolerance, new wheels and springs, and no variable supplies, the maximum static height of each overhauled locomotive must not exceed 15 feet 4.75 inches.

2. Each overhauled locomotive must be measured to determine the maximum height.

3. Measurement sheets must include any calculations addressing the effect of variable supplies at the time of measurement, and shall be included in the Vehicle History Book.

4. Mirrors/wind deflectors, when folded outward, will not be subject to diagram width requirements, but must be shown on clearance diagram required in **Part 23.03**.

B. The overhauled locomotive shall comply with the requirements of AAR diagram "Clearance Lines for Third Rail Territory" (included in Figure A1 - **Appendix F**), which shall be shown on new Clearance Diagram.

1. See Part 23.03 for clearance diagram requirements.

C. The Contractor shall submit to the Authority complete dimensioned plan and elevation views of any proposed modification to the locomotive for review and acceptance before proceeding

with any final body modifications.

1.11 MAINTENANCE INSTRUCTIONS

A. The latest revision of the EMD/OEM maintenance instructions shall govern the rebuilding of major components, supplemented by the Contractor's procedures which must be submitted for review and acceptance by the Engineer.

1.12 EQUIPMENT NUMBERS

A. Locomotives shall retain their current road numbers.

1.13 PERFORMANCE

A. General

1. As built and after overhaul, locomotives shall be capable of meeting the following:

a. Speed: 103 mph (166 kmph) maximum on level, tangent track.

b. Gradeability: 3% maximum.

c. Weight of cars to be pulled: 175,000 lb. (73,379 kg) per car.

d. Number of cars to be pulled: Ten (10) maximum.

e. Horizontal Curve:

i. Single unit - 176 ft. radius (33 degrees) minimum.

ii. Coupled to train - 288 ft. radius (20 degrees) minimum.

f. Requirements 1.13A.1a, b and c are individual and not simultaneous with each other.

B. Sound Emission Levels

1. With equipment as described in the Specification, sound emission levels of the locomotive shall meet the requirements shown in **Part 19.04G**.

1.14 EMISSIONS

A. The Contractor shall utilize replacement parts and procedures as required so that the completed engines as installed in the locomotives will be in compliance with EPA Tier 0+ requirements for exhaust emissions in accordance with 40 CFR 92 regulations.

1. Procedures shall include any testing necessary to demonstrate and achieve EPA compliance.

2. The Contractor shall provide to the Authority an EPA certification that the locomotives are in compliance when delivered.

PART 2.00 – CARBODY

2.01 GENERAL

A. All material and workmanship associated with the repair of components shall be of high quality and shall conform in all respects to the best industry overhaul practices for railroad locomotives.

B. Stripping

1. Strip the locomotive, including the removal of all major equipment items, sufficient to enable a complete inspection of the underframe and structural members of both the underframe and carbody.

2. Clean the underframe, center sill, and body bolsters down to sound paint.

C. Restoration

1. Use structural materials for replacement and repairs which are equivalent to those used for the original construction. Where unknown, steel equal to or stronger than ASTM A36 shall be used for structural members.

2. Repair or replace any structural or supporting member whose cross- sectional area has been reduced by 10% or more.

3. Insulate and weatherproof the finished locomotive to meet all applicable FRA standards and to meet the requirements of the watertightness test per Part 19.00.

4. Drain holes, weatherstripping, sealants, and other measures shall be used to prevent premature carbody deterioration.

5. The collision strength of the underframe and structural components of the finished overhauled locomotive shall be equivalent to that of a new locomotive.

D. Painting

1. Following completion of all exterior overhaul, modification, and repair work, prime and paint the exterior and interior in accordance with **Part 11.00**.

2.02 STRUCTURAL CONSIDERATIONS

A. General

1. Locomotive is designed to accommodate a buff load of 800,000 pounds without permanent deformation of any part of the underframe.

2. Overhaul work shall be designed to preserve buff load strength in accordance with the requirements of 49 CFR 229.141

3. See also Part 19.04S.1.

4. Subpart D of CFR Section 229 maintains that all locomotives manufactured or

remanufactured on or after January 1, 2009 must adhere to the new locomotive crashworthiness design requirements. A remanufactured locomotive means a locomotive rebuilt or refurbished from a previously used or refurbished underframe ("deck"), containing fewer than 25% previously used components (measured by dollar value of the components). For calculation purposes, the percentage of previously used components is determined with equivalent value of new parts and is calculated using dollar values from the same year as the new parts used to remanufacture the locomotive. The remanufacture of this locomotive must contain more than 25% previously used components (measured by dollar value of the components).

2.03 UNDERFRAME

A. Inspect the underframe for cracks and alignment, including bolster centers, and correct all defects.

B. Replace all traction motor blower bellows assembles.

C. An "F" letter shall be located at the No. 1 end of each side sill.

2.04 EXTERIOR LOCOMOTIVE BODY

A. Clean and inspect entire exterior of locomotive for corrosion and damage.

1. Small tears, holes and cracks that have penetrated through the car body sides, ends and roof shall be welded closed, the area grit blasted clean, body putty applied and ground smooth, and the area primed in preparation for painting.

    a. Use of body putty although not prohibited will be allowed only at the discretion of the Authority.

2. Minor dents, deep scratches, brush-burns, and corroded areas, that would be noticeable after finish painting shall be grit blasted clean, body putty applied and ground smooth, and the area primed in preparation for painting.

3. Where corrosion has penetrated more than 40% of the side or end sheet metal, a patch plate to restore original thickness shall be welded over the affected area after the corroded area has been grit blasted clean and a rust inhibitor primer applied.

    a. The patch plate shall be welded in place with weather-tight seal weld, the weld ground smooth, and primer applied to the weld and patch plate in preparation for painting.

4. All welds in car body side sheets shall be ground smooth.

5. Particular attention shall be given to minimize distortion of side plates during welding.

6. Dents shall be properly repaired by straightening to present an unblemished finish.

B. Major exterior locomotive components shall be welded steel construction utilizing appropriate materials, subject to acceptance by the Engineer.

C. Doors

1. Doors, door latches, seals and hinges shall be replaced with new.

a. Door lock (rear end) shall be renewed (see Figure H20).

b. Weatherstripping shall be replaced with new Durox seals.

2.05 LONG HOOD

A. Existing side body engine room doors must be cleaned, inspected, and repaired to correct wear and assure positive latching.

2.06 SHORT HOOD

A. Access doors and plates shall be maintained, modified, or provided on short hood for access to air brake equipment, sand traps, and other equipment as required.

2.07 INTERIOR CAR BODY

A. The entire interior of the locomotive body shall be thoroughly cleaned of dirt, grease, and oil and then inspected for corrosion and damage.

1. All damaged areas shall be repaired and primed.

B. Shutter valves, operators, and shutter assemblies shall be cleaned, inspected, tested, and repaired or replaced as required.

C. Engine cooling water tank and filler necks shall be cleaned, inspected, leak-tested, and overhauled or replaced in accordance with guidelines noted in latest issue of the following MI, and new caps shall be applied

1. M.I. 550 - Locomotive Radiator Assembly and Installation

D. All cooling fans, including HEP cooling fans (unless replaced per **Appendix E**), dynamic brake fans and motor assemblies shall be cleaned, inspected, tested, and overhauled or replaced, and balanced as required in accordance with guidelines noted in latest issue of:

1. M.I. 4102 – 48" AC Motor Driven Cooling Fan

2. M.I. 4105 – 48" AC Motor Driven Quiet ("Q") Cooling Fan Single and Two Speed

E. Plug type disconnects shall be maintained on all cooling fan motors.

F. Circuit overload protection shall be maintained for all cooling fan motors.

G. Inertial air discharge motors and fans shall be cleaned, inspected, tested, and overhauled or replaced in accordance with guidelines noted in latest issue of:

1. M.I. 3614 – Inertial Air Discharge (Filter Blower and Motor) Hatch Assembly

H. Inertial filters shall be removed, cleaned, inspected, and qualified or replaced.

I. Following completion of all interior locomotive modifications and repair work, it shall be painted in accordance with **Part 11.00**.

2.08 END ARRANGEMENTS

A. No. 1 End (Front)

1. Remove the snowplow, clean and inspect the end plate and anticlimber on front of locomotive for damage, and repair or replace them as required to restore to original construction.

2. Repair or replace the snowplow and reinstall it.

3. Huck type fasteners, or equivalent, shall be used for reapplication of the snowplow.

B. No. 2 End (Rear)

1. Inspect the end plate and anticlimber and repair or replace as required.

2. Clean and inspect buffer plates at rear of locomotive for damage, and repair or replace as required to return them to original construction, (Figure H60, in **Appendix F**).

3. End platform safety chains shall be retained..

C. Couplers and Draft Gear

1. Type F Coupler is provided at both ends.

a. Coupler and yoke shall be replaced with new at No. 2 end.

b. No. 1 end coupler and yoke shall be inspected and, if required, overhauled to comply with AAR Standards and 49 CFR 229.61.

c. New or repaired, top operated uncoupling devices, arranged to operate from either side of the locomotive, shall be provided.

d. New spring loaded type M carriers with 0.25 x 4.25 x 13.88 in. manganese wear plates shall be provided

2. Draft gear at each end of the locomotive shall be National Casting Division No. NC390 draft gear.

a. Draft gear and draft gear housings at the no. 2 end shall be new, and overhauled if required at the no. 1 end.

i. All cushion elements shall be new.

ii. All new hardened bushings, pivot pins, and all alignment control features shall be provided.

iii. Draft system should adhere to the regulations provided in Section 229 of the Code of Federal Regulations Subpart A (§229.61).

iv. A device shall be provided under the lower end of all drawbar pins and articulated connection pins to prevent the pin from falling out of place in case of breakage.

2.09 GENERAL CAR BODY

A. Provide new Class BC, Ansul Dry Powder fire extinguishers at the following locations (3 per locomotive):

1. One (1) twenty (20) pound (9 kg) extinguisher in cab.

2. One (1) twenty (20) pound (9 kg) extinguisher in each end of engine compartment.

B. Modifications and repairs to the carbody shall receive suitable acoustical treatment to reduce noise emission.

C. All steps, grab irons, and other safety appliances shall be cleaned, inspected, and repaired or replaced to meet the requirements of 49 CFR 231.

PART 3.00 – OPERATING COMPARTMENT

3.01 INTERIOR

A. Ceilings and side sheets shall be cleaned, inspected, and repaired or replaced in kind.

B. Side paneling under windows shall be removed, area thoroughly cleaned of dirt and corrosion, and inspected to determine the extent of repairs, and all materials replaced in-kind.

C. Underfloor and short hood compartments shall be thoroughly cleaned and repainted.

D. Interior of main compartment shall be completely repainted and re-lettered.

E. Stainless steel operator's foot rest shall be cleaned and repaired, as required.

3.02 SEATS

A. Operator's seat (right side) and observer's seat (left side) shall be new USSC Group, 4 way adjustable, lumbar support, fore and aft adjustable, high back seat, wall mounted, model #9010, or Engineer approved equal.

1. Coverings shall be tuff tex and color to be approved by the Authority

2. Seat including mounting shall meet AAR Standard S504.

3. Wall mounted track shall be reinforced if required.

B. Jump seat shall be added, location and attachment method shall be approved by the Engineer.

1. Seat model shall be approved by the Engineer

2. Covering shall match operator's seat.

3.03 HEATING, VENTILATING, AND AIR CONDITIONING

A. Existing 74 volt cab heaters and layover heaters including guards are obsolete and shall be replaced with new unit approved by the engineer.

1. This may require modifications to the cab interior front wall, to accommodate the replacement model.

B. All Salem ventilators shall be replaced, except roof unit (see **Part 14.02C**).

C. All switches and nameplates shall be replaced with new.

D. See Part 14.01 for air conditioning system.

3.04 INSULATION

A. All insulation shall be renewed with non-flammable, thermal and acoustic type insulation; installation shall meet FRA requirements.

1. Non-flammable thermal and acoustic insulating material shall be reinstalled as required for repairs, or for original installation or modifications.

2. The Contractor shall submit his recommended material for thermal and acoustic insulation, including samples, to the Authority for review and acceptance, prior to procurement of the material.

3.05 FLOORING

A. Existing one inch thick Benelex flooring, or Authority-approved equal, shall be replaced in-kind with new and shall meet FRA requirements.

B. Existing three piece trap door shall be rehabilitated or replaced, and all hardware shall be renewed.

1. Center supports shall be removable.

3.06 GLAZING, DOORS, AND WINDOWS

A. New FRA approved glazed heat treated windshields shall be installed with new aluminum frames for rust protection.

1. Windshields shall be electrically heated per existing installation.

2. Particular attention shall be paid to removing and repairing any rotting portions of the window areas.

B. Cab doors shall be thoroughly cleaned and repaired.

1. Fixed windows shall be replaced with new.

2. New latches and locks shall be applied.

3. Door locks shall be keyed to accept MBTA standard key as shown in Figure H20 (**Appendix F**).

C. Durox cab door and engine room door seals shall be replaced with new.

D. All weatherstripping shall be new.

E. All cabinet doors and other access doors and panels including hardware shall be cleaned, inspected, and repaired or replaced as required.

F. Moveable and fixed windows including sash, track, and latches shall be cleaned, inspected, tested and repaired or replaced as required, and all weather stripping renewed.

1. Side window glazing that is broken, cracked, crazed, clouded or damaged in any way shall be replaced.

3.07 MIRRORS/WIND DEFLECTORS

A. The Prime No. SC875-28 wind deflectors shall be cleaned, inspected or replaced in-kind.

B. New weatherproof padded arm rests shall be installed on both sides of the cab at the lower edge of operable portion of the side windows.

1. Armrests shall be applied in a manner to prevent water buildup between the armrest and cab.

3.08 WINDSHIELD GUARDS

A. All hardware, attachment points or other remnants of the previously installed windshield guards shall be removed.

B. After removal of all windshield guard items, the carbody should be smoothed, as necessary, prior to painting so that no indication of the prior installation is visible.

3.09 WINDSHIELD WIPERS

A. Windshield wipers shall be replaced with new, electrically operated wipers, as approved by the Engineer.

3.10 CONTROL STAND

A. Existing control stand and all components included therein shall be disassembled, cleaned, repaired as required, or replaced, except as listed below:

1. All lamps shall be new, LED where possible, see Part 15.00.

2. All switches shall be new.

3. Model, Make and location of newly installed bell switch to be approved by the Authority

4. All engraved stainless steel name plates shall be refurbished or replaced, as required.

5. All insert type name plates shall be replaced as necessary.

6. Radio rack and control head mounts, and PA rack and control head mounts, shall be repaired as required.

7. Repaired stand shall be repainted (per Part 11.06).

8. Reverser controller shall be removed and rebuilt to OEM specifications.

3.11 OTHER OPERATOR'S CONTROLS

A. The engine control (isolation) panel shall be cleaned, inspected, tested, and components repaired or replaced as required. Refurbish or replace all name plates.

B. The HEP Cab Remote Panel shall be cleaned, inspected, tested, and components repaired or replaced as required. Refurbish or replace all name plates.

3.12 SAFETY CONTROL

A. Existing safety control system shall be replaced, per **Part 10.03**.

3.13 MISCELLANEOUS COMPARTMENT REQUIREMENTS

A. Refurbish or replace all other name plates or tags in the locomotive cab.

B. Trac Products Model BS-7081 waste container shall be repaired, with removable stainless steel insert and connecting sash chain added if not installed.

C. Card holders for FRA card forms, Prime SC-960, shall be repaired or replaced.

D. Existing perforated work book holder 9 in. wide by 11.5 in. long by 1.5 in. deep shall be repaired or renewed.

E. New perforated stainless steel holder designed by the Contractor shall be provided for Amtrak MAP forms.

F. Noise Emission and Glazing Compliance Plates shall be provided and installed by the Contractor or existing items cleaned and repaired indicating conformance with CFR 49 223 and 210 respectively (Figures G76 and G80 in **Appendix F**).

G. Safety chain across stairwell to short hood shall be provided.

H. Four new padded sun visors shall be applied, two on each side of the front of the cab.

PART 4.00 – TRUCKS

4.01 TRUCK ASSEMBLIES

A. Existing trucks on the locomotives shall be removed from the locomotive, completely disassembled, visually and magnetic particle inspected, overhauled, and reinstalled.

1. Trucks shall be overhauled in accordance with guidelines noted in the latest issue of the following EMD M.I.s:

a. 1504 – GP Truck Assembly with Single Brake Shoe Rigging

b. 1512 – Coil, Elliptic and Rubber Truck Spring Qualification and Replacement

B. Trucks shall be equipped with new or unit exchanged yaw damping devices, new journal box coil springs, new steel elliptic low profile secondary springs and new lateral and vertical shock absorbers.

1. All shock absorbers and related rubber grommets and metal bushings shall be replaced.

C. New non-metallic Nylatron pedestal liners shall be supplied and installed.

D. Truck and truck parts shall be fully interchangeable with similar items on other existing F40 style Authority locomotives.

E. No part of the running gear, except the wheels and flexible non-metallic sand nozzles, shall be less than 2 1/2 inches above top of rail in accordance with FRA requirements.

1. These minimum requirements shall be maintained under all wheel sizes and spring conditions.

F. Normal wear of truck components shall not significantly affect the safe, stable and comfortable operation of the locomotive.

4.02 WHEELS

A. All new wheels shall be installed.

B. Wheels shall be AAR Class “B”, in accordance with AAR Specification M107, latest issue.

1. Wheels shall have AAR-1B tread profile.

2. Wheels shall incorporate a 36 in. diameter index groove machined on the outer rim of the wheel.

C. Hub shall be stamped in accordance with the alternate marking per Figure 5 of AAR Specification M-107, Appendix B .

D. Wheel and axle mounting shall be done in accordance with the AAR Wheel and Axle Manual, Section G – Part II of the AAR Manual of Standards and Recommended Practices in a shop certified by the AAR.

4.03 AXLES

A. Bearings, wheels and drive/axle gears shall be dismounted and axles shall be requalified in accordance with the AAR Wheel and Axle Manual, of the AAR Manual of Standards and Recommended Practices in a shop certified by the AAR.

1. Only requalified axles with standard journal bearing seats are permissible for reuse.

2. Axles which do not requalify shall be replaced with new Class "F" axles, AAR Spec. M-101.

a. Axles shall be splined on the gear end only.

B. Axle bearing adapter wear plate shall be inspected and replaced if necessary.

4.04 BEARINGS

A. Existing Timken H337844-90165 journal roller bearings on the locomotives shall be remanufactured, in accordance with the guidelines noted in the latest issue of the following EMD M.I, and reapplied on the locomotives:

1. M.I. 1553 – Grease Lubricated Cartridge-Type Journal Bearings

B. Bearing remanufacture and application shall also be in accordance with the AAR Roller Bearing Manual, Section J, of the AAR Manual of Standards and Recommended Practices in a shop certified by the AAR.

4.05 JOURNAL BEARING ADAPTERS

A. Existing journal bearing adapters shall be rebuilt in accordance with guidelines noted in the latest issue of the OEM instructions, or Authority-approved Contractor procedure.

4.06 TRUCK BRAKES

A. The existing trucks are standard EMD GP trucks with single shoe brakes.

B. New composition Cobra V330 brake shoes shall be provided and installed.

C. Pin type slack adjusters shall be cleaned, inspected and repaired or replaced in kind.

D. All new brake pins and bushings shall be provided which shall be hardened and ground.

E. Brake cylinder and piston assemblies shall be replaced with new.

F. See Part 17.01G for other requirements.

4.07 GEARING

A. All 57 tooth drive gears shall be requalified and or reprofiled in accordance with the guidelines noted in the latest issue of:

1. EMD M.I. 1518 – Wheels, Axles, Axle Gears and Pinions

B. All new gear cases shall be installed, using high capacity cases, with Plastic Ever Seals.

1. Gear cases shall be fitted with inspection covers with quick-access latches.

2. Bolted construction shall be used for the gear case.

4.08 SPARE TRUCKS

A. Contractor to provide four (4) fully equipped trucks matching proposed configuration and arrangement of those overhauled for the locomotives.

1. Frames and all other components shall be provided by the Contractor.

B. All components shall be in accordance with this section, and other applicable requirements of this specification,

C. Equipped trucks should be built and delivered to the Authority no later than 6 months after NTP.

4.09 MISCELLANEOUS

A. Cab signal speed control axle generator shall be replaced with new. Removed units shall be returned to the Authority.

B. Check bolster center area and main frame for alignment and cracks.

C. All traction motor nose suspension assemblies, guide pins, and wear plates shall be replaced.

D. Prior to re-assembly of the trucks, they shall be thoroughly cleaned of dirt, grease, oil, rust, primed and painted with a coat of Authority approved paint that will not conceal cracks that may develop in service.

PART 5.00 – ENGINE SYSTEM

5.01 ENGINE

A. The locomotives are each equipped with an EMD 645 E3C engine with 3,000 nominal horsepower for traction, sixteen (16) cylinders, water cooled, vee type diesel, turbocharged.

B. Engine and Component Overhaul

1. Engine shall be overhauled in accordance with the latest O.E.M. standards and Maintenance Instructions and shall also comply with the Authority's Specification attached as **Appendix D** and the latest issue of:

a. EMD M.I. 9666 – Turbocharged Engine Upgrade Conversions – Locomotive Engines

2. Should the Contractor choose to overhaul the equipment himself, or subcontract the overhaul with a supplier who is not the O.E.M., it shall be the Contractor's responsibility to demonstrate to the satisfaction of the Engineer the adequacy of Contractor's or vendor's facility, equipment, and procedures.

C. A replacement data plate shall be attached to the side of the engine block showing the name of the rebuilder, the date of the overhaul, the serial number of the engine, and any other pertinent information.

D. Contractor shall provide all labels and certifications required by 40 CFR 1033.

5.02 AIR FILTRATION

A. Primary Carbody Air

1. The inertial filter screen and elements and shall be removed, cleaned and repaired or replaced as required.

2. Overhaul the bleed air ("dust bin") blower and motor in accordance with latest issue of:

a. EMD MI 3612 – Auxiliary Generator and Blower Assemblies

3. The main generator and traction motor blower assembly shall be cleaned, inspected, tested and rehabilitated or replaced and mated and balanced in accordance with latest issue of:

a. EMD MI 3612 – Auxiliary Generator and Blower Assemblies

b. In lieu of rehabilitating the blower assembly, it may be UTEXed with the OEM.

B. Engine Intake Air Filters

1. The existing paper engine air intake filter assembly shall be replaced with an appropriately sized "baggie" filter assembly similar to that in MBTA's HSP46 locomotives.

5.03 ENGINE COOLING

A. Mechanical bonded radiator cores shall be cleaned, inspected, tested and repaired in accordance with the latest issue of M.I. 549 – Water Cooing Radiators, with the exception of the following, or replaced:

1. Headers and spacers are to be qualified for reuse or replaced with new.

2. No tubes are to be crimped or plugged.

B. The electric drain valve which provides a positive drain of the cooling system when cooling water temperature approaches freezing point shall be replaced.

1. The drain valve shall be tested to open at 45 degrees F (7 degrees C).

5.04 TEMPERATURE CONTROL

A. A new electronic control system, shall be provided to control sequencing of the cooling fans and shutter controls (see **Part 12.05**).

5.05 ENGINE EXHAUST

A. The exhaust system shall be equipped with a removable cover for inspection of adapter and turbocharger screen assembly.

B. The exhaust system ejector assembly shall be removed, cleaned, repaired as necessary and reinstalled.

5.06 ENGINE HOUR METER

A. Elapsed engine hours shall be recorded by means of a service proven electro- mechanical non-resettable meter with six digit readout (999,999.9) and 3.5 inch (88.9 mm) bezel, mounted in a location acceptable to the Engineer.

5.07 RETENTION TANK

A. The retention tank shall be thoroughly cleaned inside and out. The tank shall be inspected, tested and repaired or replaced as necessary. The drain valves and inspection cover gasket replaced with new.

5.08 ENGINE CONTROL SYSTEM

A. See Specification Part 12.05.

PART 6.00 – FUEL SYSTEM

6.01 FUEL TANK

A. Fuel tanks shall be cleaned inside and outside, inspected, and repaired as required

B. The Fuel tank shall be drained, removed, cleaned, inspected for damage, leaks and repaired as required.

1. The tank shall be requalified to meet the OEM standards.

2. Internal baffles shall be inspected and repaired as required.

3. The fuel tank sump drain valve, and the protective plates to protect it from damage by debris, ballast, etc., shall be cleaned, inspected, and repaired or replaced as required.

4. Fuel tanks will be thoroughly cleaned and painted after all repair and modifications are complete.

5. Two new Houston H3000 fuel filers shall be installed.

C. All gauges shall be replaced with new.

D. Fuel sensors shall be installed per **Part 16.04**.

E. Suction and return lines shall be replaced with new.

F. New sight glasses shall be installed

6.02 FUEL ADAPTERS

A. Replace all tank mounted components of the Houston automatic fuel shut off system including float switch, cable, and filler adapter.

B. Repair or replace etched stainless steel signs on side sill with 1" red painted filled letters "FUEL", similar to EMD dwg. 8350090.

6.03 FUEL LINES

A. Fuel suction and return lines from fuel tank to fuel pump shall be renewed.

B. The fuel suction strainer shall be removed, thoroughly cleaned, inspected, and repaired or replaced as required.

1. Replace wire mesh filter element and "O" ring at reassembly.

C. Modify fuel suction line so as to be attached to the fuel tank by a bolted on manifold for ease of servicing.

D. Replace fuel oil preheater and thermostatic valve.

6.04 EMERGENCY FUEL CUTOFF

A. The system shall be cleaned, inspected, tested, and repaired as required to meet the requirements of 49 CFR 229.93.

B. Install water tight junction boxes to emergency fuel cutoff actuating push buttons located on each side of the fuel tank.

C. When actuated, both the main engine and the head-end power engine shall stop immediately.

D. New multi-layered acrylic identification plates with 0.5" white letters "EMERGENCY FUEL SHUT OFF" in red background shall be provided for each button, arranged to replace EMD p/n 8362466, using same mounting points but with width increased to seven (7) inches, and the design or a sample submitted for review and acceptance by the Engineer.

    1. Engraving method shall use broad stroke lettering as close as possible in appearance to specified font (Figure G1 in **Appendix F**).

6.05 FUEL PUMP AND MOTOR

A. Fuel pump and motor shall be replaced.

PART 7.00 – HEAD END POWER

7.01 OVERVIEW

A. The locomotives are currently equipped with separate head end power (HEP) system which supplies trainlined power to coupled coaches for heating, lighting, air conditioning, and other auxiliary loads.

B. The HEP system consists of a skid-mounted Caterpillar 3412 diesel engine coupled to a 600 KW Marathon 571 RSL 4857 special railroad duty alternator, with related auxiliary equipment and controls.

C. The head end power system is completely independent of the locomotive's main propulsion, prime mover engine:

1. Traction power is not used for head end power.

2. Head end power is not utilized by the traction power system, except for layover protection.

D. The Contractor shall remove the skid-mounted HEP genset, perform all activities described in this specification, reinstall the units in the locomotive and test as specified.

1. The existing engine-generator sets are removable, as a single unit, through a roof hatch, and this capability shall be maintained.

2. A system of quick disconnect-type connections is applied to cooling, exhaust, and electrical systems to allow ready removal of the roof hatch, and this capability shall be maintained.

E. All engine maintenance and overhaul activities shall be performed in accordance with Caterpillar recommended practices and work instructions, including "The Operation and Maintenance Manual" Caterpillar #SENR 2559 and all applicable documents referenced therein.

1. All maintenance shall be performed by a certified Caterpillar repair facility using Caterpillar trained mechanics.

2. All materials and components shall be as required by Caterpillar recommended practices and work instructions.

F. All work performed on the Marathon Alternator shall be in accordance with Marathon recommended practices and work instructions, using Marathon recommended materials and components.

G. All replacement parts for HEP engine/alternator shall be OEM approved

7.02 REMOVAL OF HEP UNIT

A. Each engine-generator set shall be removed from the HEP Compartment.

1. The HEP compartment shall be cleaned and painted per **Part 11.00**.

7.03 DIESEL ENGINE

A. Each diesel engine shall be completely disassembled, cleaned and inspected. The MBTA shall be immediately advised of any required additional repairs not included in this base contract.

1. Inspect and measure engine block and components to meet OEM recommended specifications.

2. Magnaflux cylinder block, crankshaft, and camshaft for possible cracks.

B. At a minimum each engine overhaul shall include the replacement of the following items:

1. Replace cylinder heads with Caterpillar remanufactured parts

2. Replace pistons, rings, pins, lock ends, liners and liner seals with new Caterpillar parts

3. Replace connecting rods using new Caterpillar parts

4. Replace oil cooler core with a Caterpillar remanufactured part

5. Replace main water pump with a Caterpillar remanufactured part

6. Replace fuel injection nozzles with Caterpillar remanufactured parts

7. Replace main oil pump with Caterpillar remanufactured unit

8. Replace turbocharger cartridge with Caterpillar remanufactured parts

9. Replace main and rod bearings with new Caterpillar parts

10. Replace front and rear seals with new Caterpillar parts

11. Replace timing gear bushings new Caterpillar parts

12. Inspect crankshaft, camshaft, lifters and pushrods for re-qualification

13. Replace lifter springs with new Caterpillar parts

14. Replace block heater with new Caterpillar part

15. Replace all filters (including air) and add oil with new Caterpillar parts

16. Replace exhaust manifold studs with new Caterpillar parts

17. Replace turbo mounting hardware with new Caterpillar parts

18. Replace all gaskets and seals with new Caterpillar parts necessary to complete the rebuild

19. Replace all belts, and hoses with new Caterpillar parts

20. Clean and inspect after cooler core

21. Clean, test and inspect fuel injection pump and submit written report

22. Replace fuel shut-off valve with a new OEM part

23. Install a new IR air starter

24. Replace engine mounted electrical switches and sensors with new Caterpillar components utilizing OEM wire routing and securement.

25. Replace thermostats with new Caterpillar parts

C. The rebuilt engine will be Dynamometer tested at the manufacturer's facility to verify that the engine performance is within the criteria acceptable by Caterpillar for a remanufactured engine.

7.04 ALTERNATOR

A. Perform the following tests on the stator and rotor to ensure compliance with OEM test criteria. The Contractor shall provide a report of the results of the electrical testing prior to disassembly.

1. Megger test

2. Surge comparison test

3. Lead-to-lead low resistance test

B. Completely disassemble and inspect all parts.

1. Windings shall be completely tested for requalification per OEM recommendations. Windings shall be steam cleaned, baked and dried per OEM recommendations.

2. Windings shall be megger tested after drying and the results recorded for inclusion in the documentation.

3. All other parts shall be steam cleaned and pressure washed per OEM recommendations.

4. Using a micrometer, check all critical fits and clearances. Measure and record all dimensions for inclusion in documentation.

5. Each alternator diode bank shall be replaced with new.

6. Supply and install new low voltage control terminal boards

7. Supply and install new insulated standoffs.

8. Each alternator stator and rotor will be dipped and baked with a solventless, Class "H" polyester varnish and finished with a final spray overcoat of a compatible epoxy varnish, such as Sterling U-674 or MBTA approved equal.

9. Each alternator shall have the bearing housing measured and machined if necessary.

10. Each alternator shall have a new OEM main bearing installed. If machining of the housing is required, prior approval from the MBTA is required.

11. Assemble alternator per OEM instructions. Test and check endplay per OEM recommendations. Measure and record endplay for inclusion in documentation.

12. Dynamically balance the rotor.

7.05 HEP SKID FINAL ASSEMBLY

1. Each base frame will be thoroughly inspected to ensure integrity of the frame. Any cracks or uneven surfaces will be repaired prior to unit assembly.

2. Each base frame will be primed and painted on all surfaces prior to unit assembly.

3. After mounting of the engine and alternator and prior to securing to the base frame, each unit will be shimmed as required under the mounting feet of both engine and alternator to assure proper alignment.

4. All new, grade 8 fasteners, of the proper size will be supplied for all mounting feet. All hardware will be properly torqued and marked.

5. Each assembled unit's crankshaft end play to be measured and recorded to be within manufacturers specifications.

6. Each HEP unit to be completely re-wired utilizing Exane type wire rated at 2000vdc.

7. All HEP units to have all new rigid conduit installed to assure complete protection for all wiring.

8. All wiring shall be point to point wiring, with no butt slices permitted.

9. Each HEP unit shall include a new oil pressure switch rated at 74 VDC.

10. Each HEP unit shall include new style temperature switches rated at 74 VDC. Ratings for switches shall be 203 degree F and 223 degree F.

11. Each HEP unit shall have a new gage panel with (4) liquid filled gages for oil temperature, water temperature, oil pressure and turbo boost.

12. One Hobbs 9831, electro-mechanical, non-resettable engine hour meter with a 558-M mounting bracket and damper.

13. Each HEP unit to have a new Magnetic pick up installed, properly adjusted and connected via the OEM plug type connector.

14. Each HEP unit to have a new Woodward EG3-PC proportional fuel actuator installed.

15. Each HEP unit to be properly primed and painted as follows:

    a. Engine –Caterpillar Yellow

b. Alternator- Suede gray

c. Base frame – Suede gray

d. Drip pan – Suede gray

16. Each HEP unit shall include a new Kim Jacket water heater rated at 4000 watts, 480 VAC.

17. Each HEP unit shall have a new Nelson emission absorber installed. All vent lines to be properly supported and routed to the engine drip pan.

18. The builder's original serial number plate shall be retained and this number shall be recorded on all build up sheets.

19. A separate rebuilder's plate is to be attached beside the original builder's serial number, which shall only document the date of completion (month and year).

7.06 HEP INSTALLATION AND TEST

A. The Contractor shall reinstall the HEP skid package in the locomotive.

1. Air, fuel and water piping shall be reconnected and pressure tested to find and repair any leaks in their systems.

2. Electrical power and control connections shall be restored and a megger test of the control circuits performed.

B. HEP Final Testing

1. The HEP system shall be tested in accordance with **Part 19.00**.

7.07 OPTION – HEP TIER II UPGRADE

A. The Authority, may choose to exercise the option to upgrade the HEP system in an agreed upon quantity of locomotives to EPA Tier II compliance. In that instance, the scope of work in **Appendix E** would be performed in lieu of the work otherwise specified in **Part 7.00** for the associated locomotives.

PART 8.00 – LAYOVER HEATING

8.01 SYSTEM

A. Layover heating systems for the prime mover and head end power engines are provided, which are electrical systems completely independent of all other locomotive and train heating systems and independent of each other.

B. Layover systems are designed to maintain engine and cab interior temperatures of 50 degrees F (10 degrees C) with an outside ambient temperature of -30 degree F (-34 degree C).

8.02 POWER SOURCE

A. 480 volt, 3 phase, 60 hertz train line electrical power is utilized for the layover heating systems.

1. Trainline power is obtained from either:

a. Wayside layover power station.

b. Head end power unit to provide layover power for prime mover.

2. The system as presently installed permits wayside power to be plugged into a single head end power receptacle at the front end or rear end of the locomotive, or any other single receptacle in the train, with additional cables as required to provide loop circuit protection, and this capability shall be maintained.

8.03 METHOD

A. Electric heaters are installed in the prime mover and head end power engines cooling and lubrication systems with electrically driven, thermostatically controlled pumps which circulate heated cooling water and lube oil through, or around, the engines, air compressor, radiators, and water storage tanks, and any other associated equipment requiring protection from freezing.

B. Operating Compartment

1. Power for layover heating by a standby heater is provided from the 480 volt AC head end power train line.

2. Standby heater system in the locomotive cab shall be removed, cleaned, tested in accordance with **Part 8.04**, and repaired or replaced as required.

8.04 REHABILITATION

A. The prime mover engine layover heating system shall be thoroughly cleaned, and tested in accordance with the manufacturer's instructions.

B. Rehabilitation of the prime mover layover heating system shall include, but not be limited to the following:

1. Direct current and high potential ground tests of the entire control and power system.

2. Inspect and test the circulating pump and motor assemblies and piping for the lube oil and cooling water systems, and repair or replace as required.

    a. Install new motor overload protection circuit breakers in pump circuitry, as approved by the Engineer.

3. Replace all immersion heaters, pumps and safety devices.

4. Clean, inspect, and test, switches, circuit breakers (except new circuit breakers installed per **Part 8.04B.2.a**), relays, contactor.

5. Renew all fuses.

6. Refurbish all name plates or renew.

7. Any other defective component shall be repaired or replaced as required.

8.05 CONTROLS

A. Layover Switches

1. Layover switches are provided and interlocked such that when in the ON position it is impossible to start either engine when connected to the layover heating system.

2. Should the engine be running and a switch be placed in the ON position, the indicator light in the cab will come on but the circuit to the layover system will not be completed.

    a. In the event that the engine is shut down when this condition exists, the circuit will automatically transfer to the layover system.

B. Renew all switches.

8.06 BATTERY CHARGING

A. A new 20 ampere output battery charger shall be provided to maintain locomotive battery charge and operate battery-powered equipment such as lights and radio. It shall be equipped with a boost mode to allow for starting a locomotive with dead batteries. In lieu of this, Contractor may provide an Engineer-approved battery charger that when operating on layover is capable of recharging a dead set of batteries overnight.

1. Power supply for the battery charger is the 480 volt AC, 3 phase, 60 hertz head end power trainline.

2. This charger operates only when the prime mover auxiliary generator (**Part 12.03**) is not functioning.

3. The charger is equipped with an Engineer approved charging ammeter which shall be located in an easily visible position.

4. The charger is equipped with an audible alarm which will sound when there is no output from the charger while the layover system is activated.

5. The battery charger is protected with thermal breakers, control relays, and overload relays as required.

    a. There is a breaker placed in the locomotive battery switch and breaker cabinet to allow use of the layover battery trickle charger.

    b. All protective devices shall be renewed.

6. AC ripple in the battery charger is limited to a maximum of 100 millivolts RMS under any state of charge of the batteries or any other charger load condition, either through design of the charger itself or the application of a filter to the charger output.

8.07 SAFETY DEVICES

A. Visual indication is provided on the locomotive exterior to indicate that there is layover failure into each respective layover system.

B. The visual alarm is activated by a failure in either layover heating system.

1. Visual indication consists of a red light mounted high on the outside of the locomotive near the cab, on each side.

2. Replace present exterior cab visual alarm system indicator lights with truck/ trailer type side marker lights as approved by the Engineer.

PART 9.00 – SANDING

9.01 CONTROL

A. Locomotives are equipped with basic outboard sanding.

B. Manual and electrically controlled automatic sanding is provided.

C. Initiation of automatic sanding from brake valve handle emergency position is provided.

1. Emergency sanding is not initiated at speeds below 5 MPH.

D. Emergency sand test switch shall be provided for testing of this emergency sanding system

E. Automatic sanding is provided under wheel slip conditions.

F. Control switches:

1. Manual (direction) sanding switch is basic non-latching type.

2. Lead axle sanding switch is basic latching type with indicating light to show that lead axle sanding is "ON".

G. Direction of sanding is automatically set and controlled by the forward / reverse lever on the master controller so that sand is always delivered ahead of the leading wheels of the train.

9.02 SAND TRAPS

A. Sand traps shall be replaced with new Salem 277-2 sand traps.

9.03 SAND BOXES

A. Sand boxes shall be cleaned, inspected, and repaired as required.

1. Replace cover seals with new.

2. Install cleanout and inspection plates in both front and rear sand boxes in the floor under the sand trap, subject to approval of the Engineer.

3. Clean and paint interior of sand boxes.

9.04 HOSES AND NOZZLES

A. Inspect and repair mounting brackets and supports or replace if bent, broken, or missing.

B. Replace all hoses with heavy duty integrally guarded material.

C. Replace all nozzles with EMD Part No. 8328553 nozzles.

D. Arrange complete bracket and nozzle assemblies as shown in Figure H50 (see **Appendix F**).

9.05 OVERHAUL

A. Air System:

1. Clean, flush, test, and repair or replace air piping system as required.

    a. New air piping, when required, shall be installed in accordance with **Part 21.00**.

B. Electrical System

1. Clean, inspect, test, and repair or replace electrical system as required.

    a. New electrical wiring, when required, shall be installed in accordance with **Part 21.00**.

2. Control switches and solenoids shall be replaced.

PART 10.00 – CAB ELECTRONICS

10.01 CAB SIGNAL AND SPEED CONTROL SYSTEM

A. General

1. All existing cab signal and interface wiring located throughout the cab car shall be removed, including but not limited to and related to:

    a. Cab signal equipment rack, timing module, decelostat, cab signal ADU, track receivers, speed sensors, power supply, cab acknowledge switch, interface pressure switches and cab signal/ATC penalty magnet valves and pneumatic cut-out cocks.

2. The Contractor shall furnish and install, in the short hood or other Engineer-approved location, a new 9-aspect cab signal/ATC/ACSES system similar and where possible interchangeable with the equipment that is currently installed on the MBTA's HSP46 locomotives and/or 1800 series cab cars and overhauled 1700 series cab cars. This equipment's shall be compatible for operation on the AMTRAK Northeast Corridor (NEC), in accordance with the code structure defined by Amtrak Specification S-604D.

3. The system shall provide isolated outputs capable of interfacing with the event recorder described in these Specifications.

4. The design of the system and equipment shall comply in every respect with all applicable sections of FRA regulations defined in 49 CFR 236, latest revision.

5. The equipment shall be compatible with wayside signal aspects, speed limits, and requirements as set forth in Amtrak's "Rules for Conducting Transportation", and "Brake and Air Signal Instructions".

6. Each system (Cab Signal/ATC and ACSES) shall have its own independent circuit breaker.

    a. The cab signal/ATC circuit breaker shall be renewed.

    b. A new ACSES circuit breaker shall be installed in a location approved by the engineer.

B. System Features

1. Cab signal pick-up coils shall be renewed.

2. The existing cab signal ADU shall be replaced with a new combined ADU. The combined ADU shall provide all ATC and ACSES indicators, a speedometer/speed display for both systems, as well as an overspeed and acknowledge alarm and other indications detailed in these Specifications and as approved by the Engineer.

3. Cab Signal/ATC and ACSES penalty brake applications shall be controlled by the systems through outputs to independent penalty magnet valves, WABCO Type FA4 or equivalent. A new ATC and ACSES penalty magnet valve shall be installed.

    a. Each penalty magnet valve shall control the application of a full service brake.

b. Application from an ACSES overspeed condition shall be recoverable by a running release.

c. Application from failure to acknowledge penalty (ATS) and an overspeed condition (ATC), shall not be recoverable. Reset shall require bringing the train to a stop (V-Zero is satisfied) and moving the throttle to IDLE.

4. When both ATC and ACSES are active, the ACSES civil speed limit shall govern.

5. Enforcement of ATC and ACSES may be cutout.

   a. The ATC and ACSES cutout switches shall instruct the system to de-activate the penalty brake circuits and hold the appropriate magnet valve energized.

   b. The aspects and the ADU indicators shall continue to function normally.

   c. All existing sealed pneumatic bypass cocks, for the penalty magnet valves, shall be renewed. If a magnet valve does not have a bypass cock, a new sealable device shall be installed at the appropriate location in the air system.

6. Independent on-board test functions shall be provided to test both the cab signal/ATC and ACSES portions of the system.

   a. The on-board test shall verify proper operation of the system as well as the ADU indicators and operator switches.

   b. The on-board test shall be initiated after the following conditions are met.

      i. The brakes must be applied.

         (a). The brake application shall be sensed by a pressure switch located in the brake cylinder line.

      ii. The unit must be in a Velocity Zero condition as determined by a Vital VZ detection.

      iii. The departure test switch on the ADU shall be held in the TEST position to check the system response to both high and low levels of track current.

      iv. The departure test shall also illuminate all indicators on the ADU.

      v. With the departure test switch held in the TEST position, the system shall simulate track codes in an ascending order and at each code check the overspeed and underspeed detection.

         (a). After reaching the highest code, the system then shall simulate each code in a descending order, requiring the operator to acknowledge each downward code change.

         (b). Upon completion of the test, the EPV shall be de-energized causing a full service brake application.

7. While operating within cab signaled territory, the ACSES system shall provide a Positive Train Stop (PTS) feature when a Restricting signal is encountered in advance of a RED Stop (Home Signal).

    a. This feature shall require that the operator to periodically acknowledge when running under a restricted signal aspect.

    b. Failure of the operator to acknowledge within a certain time period shall result in a penalty brake application.

    c. When a PTS is detected, the ACSES alarm shall pulse once per second and the ATC system shall request a penalty brake application and power removal to occur.

    d. The PTS bypass pushbutton switch located in the Electric locker behind the Operator's position, shall be reconditioned and relocated into the Train Control Locker.

8. The unit may also be operated in non-cab signaled territory by reducing the speed to below 20 mph and placing the Territory switch in the NONCODED position.

    a. This shall allow operation with an overspeed point of 75 mph until a valid track code is received.

    b. The NONCODED position of the switch shall be ignored by the unit unless the train speed is below 20 mph and all ATC/ATS operational requirements have been met by the operator.

9. When the locomotive is operating in the REVERSE direction, the ATC equipment shall enforce an overspeed point of 30 mph

C. Interface Equipment

1. Interface to the cab signal/ATC/ACSES equipment shall be by means of dedicated connectors.

    a. A multi-pin connector shall provide interface to all locomotive/car connections.

    b. A separate multi-pin connector shall provide interface to the Aspect Display Unit.

    c. An additional multi-pin connector shall be provided for interfacing to the recorder unit.

2. The new combined Aspect Display Unit shall use solid state, non-filament devices (i.e., LED), for indication and shall include the following devices:

    a. 9 aspects, located on the ADU as follows

        i. STOP (at 0 mph), RED

        ii. RES (at 20 mph), RED

        iii. APP/30 (at 30 mph), YELLOW

iv. 45 (at 45 mph), YELLOW

v. 60 (at 60 mph), YELLOW

vi. 80 (at 80 mph), YELLOW

vii. 90 (at 90 mph), YELLOW

viii. MAS (adjacent to 120 mph), GREEN

b. V zero indicator, YELLOW

c. Cab Signal/ATC alarm (6 pulses/sec)

d. ACSES alarm, (1 pulse/sec)

e. Overspeed indicator, RED

f. Non Cab Territory indicator, YELLOW

g. Cab Signal/ATC Cut-Out indicator, RED

h. ACSES Cut-In indicator, GREEN

i. ACSES Cut-Out indicator, RED

j. Departure Test indicator, YELLOW

k. (Independent) Brake Application indicator, YELLOW

l. Permanent Suppression indicator, YELLOW

m. ATC Speedometer Analog LED (0 to 120 mph)

n. ATC Speed digital display (2-1/2 digit, seven segment LED), RED

o. Acknowledge Switch, RED

p. Territory Switch, 2-position toggle

q. ATC Departure Test switch, BLACK

r. ACSES Departure Test switch, BLACK

s. Recorder Power OFF indication, RED

t. ACSES Speed digital display (2-1/2 digit, seven segment LED), RED

u. ATC Enforcement indicator, YELLOW

v. ACSES Enforcement indicator, YELLOW

3. Cab signal pickup coils shall be renewed.

    a. The bars shall be connected in a series adding configuration.

    b. Forward or Reverse contacts shall be used to disconnect the receiver bars when the unit is in trailing position.

    c. The 91.67/100 Hz (F1) and 250 Hz (F2) filters shall be connected to the receiver bar pair.

4. An acknowledge switch shall be incorporated within the Aspect Display Unit.

    a. The system shall require an OFF to ON transition in order to recognize the acknowledge switch operation.

    b. A penalty brake application shall occur whenever the acknowledge switch is held down for 6 seconds or longer.

5. A departure test switch for the ATC system shall be incorporated into the combined ADU.

    a. The test switch shall be a momentary action push button switch that initiates the Departure Test when pressed.

    b. Pressing the switch shall cause the system to simulate a cab signal track current of approximately 2 Amps for the 91.67/100 Hz (F1) portion and 1.4 Amps for the 250 Hz (F2) portion, allowing a check of the system response to normal track currents.

    c. The system shall also simulate a track current of approximately 1 Amp for the 91.67/100 Hz (F1) portion and 0.25 Amps for the 250 Hz (F2) portion, allowing a check that the system does not respond to low level track currents.

6. Interface to the air brake system shall consist of two (2) Penalty Magnet Valves (ATC and ACSES) and at least eight (8) pressure switches. All pneumatic devices shall be renewed. If a pneumatic device, that is listed below is not already part of the Control trailer car, it shall be added by the Contractor.

    a. The pressure switches shall be of a single break configuration and provide the following:

        i. The ATC and ACSES Permanent Suppression pressure switches (x 2) shall provide contact closure when the Brake Pipe pressure has been reduced by approximately 17 pounds.

        ii. The Permanent Suppression Initiation pressure switch shall provide a contact closure when the brake handle is moved to the suppression position.

            (a). This shall be an indication that a full suppression application has been initiated.

        iii. The On Board Test pressure switch shall provide a contact closure to allow activation of the Departure Test.

(a). The On Board Test Pressure Switch shall be a measurement of brake cylinder pressure of at least 40 psi.

iv. ATC CUT-OUT Sensing (CLOSE at 1.5 psi ↑, OPEN at 1 psi ↓)

v. ACSES CUT-OUT Sensing (x 2) (CLOSE at 1.5 psi ↑, OPEN at 1 psi ↓)

vi. Cab LEAD/TRAIL (OPEN at 100 psi ↑, CLOSE at 85 psi ↓), or electrical equivalent

7. Activation of the ATC Cutout switch shall disable the overspeed portion of the system but shall allow operation with only ATS.

   a. The ATC cutout switch shall be a sealable rotary switch mounted as part of the equipment rack.

   b. The switch shall also hold the magnet valve in the energized position allowing for Cab Signal operation but no enforced penalty.

   c. The ATC Penalty Magnet valve shall have an independent vented sealed cut-out cock.

8. Activation of the ACSES Cutout switch shall disable the Penalty Brake portion of the system.

   a. The ACSES cutout switch shall be a sealable rotary switch mounted as part of the equipment rack.

   b. The switch shall also hold the magnet valve in the energized position allowing for ACSES operation but no enforced penalty.

   c. The ACSES Penalty Magnet valve shall have an independent vented sealed cut-out cock.

   d. The ACSES cutout switch located in the Electric Locker behind the Operator's position shall be removed and made part of the new combined system enclosure installed in the Train Control Locker.

9. An inertial type Brake Assurance module shall be incorporated into the ATC/ATS enclosure.

   a. The Brake Assurance module shall provide an indication that the minimum brake rate of 1.5 mphps, compensated for grade, is being achieved.

   b. Loss of the Brake assurance signal for greater than 0.1 second, after the minimum brake rate has been detected, shall result in an immediate full service brake application.

10. The ATC/ATS system shall provide at least 16 buffered and isolated signals to the FRA Event Recorder System.

11. Contacts from the reverser shall provide interface for the direction logic.

12. The (2) Vital Velocity Zero (VZ) contacts shall be provided to the door control system.

13. The cab signal/ATC and ACSES systems' axle generator shall be renewed.

14. A contact closure indicating Throttle in IDLE shall be provided to allow reset from an ATS penalty stop and a "running release" from an ATC and or an ACSES penalty.

D. Basic Operation

1. Cab Signal Territory - ATS Operation

   a. If a more restrictive signal is received, an alarm shall sound and require the operator to acknowledge the change within 5 seconds to avoid a penalty brake application.

   b. If the operator fails to acknowledge, the penalty brake application shall be irretrievable.

   c. Recovery shall only be possible by moving the brake handle to the Suppression position, the throttle to IDLE, and achieving Vz (Velocity Zero).

2. Cab Signal Territory - ATC Operation

   a. If an overspeed condition is detected, either by a change of code or by exceeding the allowed speed (by 2 mph, ± 1 mph), an alarm shall sound and the overspeed indication shall light steady.

   b. The operator shall then have 5 seconds to initiate a permanent suppression.

   c. If a temporary suppression is initiated in the first 5 seconds an additional 5 seconds shall be allowed for the brake system to achieve either a permanent suppression or a minimum brake rate as detected by a Brake Assurance Module, or to reduce the speed below allowable limits.

   d. If the operator does not reduce the vehicle speed to below the allowable limit within the 5 second time, and neither a permanent suppression nor a minimum brake rate has been achieved, a penalty brake application shall occur.

   e. The penalty brake application shall be signaled by the alarm sounding and the overspeed indicator flashing.

   f. Recovery from the penalty application is "non-recoverable". Reset of a failure to acknowledge or overspeed penalty shall only be satisfied by stopping the vehicle (V-Zero is satisfied) and placing the throttle in IDLE.

   g. When these conditions are met, the penalty brake application shall be released and the magnet valve re-energized.

   h. If the overspeed condition is caused by a more restrictive change of code, it shall also be necessary to acknowledge the code change within the initial 5 seconds to forestall an irretrievable penalty brake application.

   i. The MAXIMUM speed (MAS) shall be set at 90 mph.

3. Cab Signal Territory - Positive Stop

    a. Upon reduction of cab signal to a Restricting Aspect and after all ATC and ATS conditions have been satisfied it shall be necessary to acknowledge the Restricting aspect at least every 60 seconds.

    b. Fifteen (15) seconds after the last acknowledgement of the ATS or preceding Positive Stop, the alarm shall sound.

    c. The acknowledging switch must be pressed within five (5) seconds of the beginning of the alarm and within sixty (60) seconds of the previous acknowledgement or ATC release to prevent a penalty brake application.

4. Non-Cab Signaled Territory Operation

    a. Upon entering Non Signaled territory the operator shall place the Territory Switch in the NON CODED position.

    b. The restricting aspect on the ADU shall be illuminated.

    c. The acknowledge alarm shall be silent.

    d. Speed shall be restricted to 79 mph.

    e. If a 75, 120, or 180 code rate, of any carrier frequency, is detected, the alarm shall sound.

    f. The operator must then place the Territory switch to the CODED position and acknowledge the alarm within 6 seconds to avoid an irretrievable train stop penalty brake application.

5. Departure Test

    a. The on-board departure test shall exercise the following areas of the system in order to verify proper operation.

    b. Code rate detection

        i. Acknowledge switch operation

        ii. ADU display

        iii. Overspeed detection

        iv. Penalty Brake application

        v. ACSES

    c. The procedure for the cab signal/ATC and ACSES departure test shall be the Authority's standard.

    d. The departure test shall verify the communication link between the overspeed and

transponder detection sections of the ACSES system.

e. In the event that the departure test is not properly completed, the system will automatically exit the departure test when speed pulses are detected.

f. The ACSES departure test toggle switch located in the Electric Locker behind the Operator's position shall be removed. The function shall be made part of the new combined system ADU.

6. Carrier Calibration

a. Carrier calibration functions shall be automated procedures that require minimal operator intervention.

i. An external cab signal loop test set is required to generate the calibration signal.

ii. Two sets shall be provided for the contract.

7. Wheel Size Selection

a. Wheel size selection shall be made available to maintenance personnel. The design shall be approved by the Authority.

b. Wheel size selection shall allow interchangeability of cardfiles between locomotives and control cars.

8. Wheel Wear Adjustment

a. Wheel wear adjustments shall be provided for the cab signal/ATC/ACSES system. Wheel wear shall be made in 0.50 inch increments. The design shall be approved by the Authority**.**

9. Speed Sensor Gear

a. All the trucks are equipped with 100 tooth bearing end caps. All systems will be required to use these components for speed sensing. If an axle end does not have a 100 tooth bearing end cap, the Contractor shall add it to the axle assembly.

E. Operating Parameter Specifications

Parameter	**Specification**
1. Carrier frequency F1 (AC nominal sine wave):	91.67 / 100 Hz (3 dB bandwidth, 89 Hz to 102 Hz)
2. Carrier F1 detection threshold:	1.4 A to 1.6 A
3. Carrier F1 detection dropout:	<1.0A
4. Carrier frequency F2 (AC nominal sine wave):	250 Hz (3 dB bandwidth, 246 Hz to 254 Hz)
5. Carrier F2 detection threshold:	0.75 A to 1.1 A

<table>
<tr><th>Parameter</th><th>Specification</th></tr>
<tr><td>6. Carrier F2 detection dropout:</td><td><0.50A</td></tr>
<tr><td>7. Aspects and rated code speeds:</td><td>
<table>
<tr><th rowspan="2">Signal Aspect</th><th rowspan="2">Aspect Display</th><th colspan="2">Code Rate (CPM)</th></tr>
<tr><th>100 Hz</th><th>250 Hz</th></tr>
<tr><td>a. MAS (100 mph)</td><td>Green</td><td>180</td><td>180</td></tr>
<tr><td>b. MAS (100 mph)</td><td>Green</td><td>180</td><td>---</td></tr>
<tr><td>c. Cab Speed (90 mph)</td><td>Yellow</td><td>270</td><td>270</td></tr>
<tr><td>d. Cab Speed (80 mph)</td><td>Yellow</td><td>120</td><td>120</td></tr>
<tr><td>e. Cab Speed (60 mph)</td><td>Yellow</td><td>270</td><td>---</td></tr>
<tr><td>f. Limited (45 mph)</td><td>Yellow</td><td>120</td><td>---</td></tr>
<tr><td>g. App. Med (30 mph)</td><td>Yellow</td><td>75</td><td>75</td></tr>
<tr><td>h. Approach (30 mph)</td><td>Yellow</td><td>75</td><td>---</td></tr>
<tr><td>i. Restricted (20 mph)</td><td>Red</td><td colspan="2">NO CODE</td></tr>
<tr><td>j. REVERSE (30 mph)</td><td>Red</td><td colspan="2">NO CODE</td></tr>
</table>
</td></tr>
<tr><td>8. Actual code rates (CPM):</td><td>
<table>
<tr><th></th><th>Rated</th><th>Minimum</th><th>Maximum</th></tr>
<tr><td>a.</td><td>75</td><td>69</td><td>79</td></tr>
<tr><td>b.</td><td>120</td><td>114</td><td>126</td></tr>
<tr><td>c.</td><td>180</td><td>171</td><td>189</td></tr>
<tr><td>d.</td><td>270</td><td>270</td><td>282</td></tr>
</table>
</td></tr>
<tr><td>9. Guaranteed Duty Cycle Response:</td><td>70% - 30%</td></tr>
<tr><td>10. Code rate pick time:</td><td>Nominal 1.6 sec + 0.4 sec</td></tr>
<tr><td>11. Code rate drop time (Low code dominant):</td><td>Nominal 3.2 sec. + 0.1 sec</td></tr>
<tr><td>12. Delay time for 5 sec. (Permanent Suppression Initiation):</td><td>+ 0, -1 sec.</td></tr>
<tr><td>13. Delay until penalty (Overspeed) (from expiration of P.S.I timer):</td><td>5 sec. + 0, -1 sec.</td></tr>
<tr><td>14. Delay until penalty (Aspect Downgrade):</td><td>5 sec. + 0, -1 sec.</td></tr>
<tr><td>15. Minimum Brake Rate (BA):</td><td>1.5 mphps</td></tr>
<tr><td>16. Speed Sensor Gear Selections (PPR):</td><td>40, 60, 100</td></tr>
<tr><td>17. Wheel Size/Wear Adjustments:</td><td>30, 31, 32
34, 35, 36
38, 39, 40
42, 43, 44</td></tr>
</table>

F. Interchangeability

1. Indicators provided for cab signal/aspect display and for speed display shall be sufficiently compact to permit mounting in a locomotive or Multiple Unit car type control stand.

2. A single indicator incorporating all information may be provided, or a two section indicator may be provided which will permit mounting differences between locomotive and car application.

G. Environmental and EMI Requirements

1. Equipment installation shall meet the manufacturer's standards concerning temperature, shock & vibration, EMC, dust tightness, oil resistant wire insulation, etc., except where in conflict with current FRA, AAR or APTA requirements.

H. Failure Data Recording System

1. The cab signal/ATC/ACSES system shall include the capability to record data associated with failures with it. Failure data shall be retained for future retrieval by maintenance personnel.

2. With each failure, the system shall record the identity of the failure, the state of input/outputs, the internal state of the cab signal/ATC/ACSES system, the date and time and any other relevant information.

3. The cab signal/ATC/ACSES system shall be capable of logging a minimum of 100 records.

4. If more than 100 records occur prior to system maintenance, the system shall log the one hundred most recent failures while keeping simple counter records of the "type" of failures for which detailed data has been overwritten.

5. A battery backup system with serviceable life of four (4) years minimum shall be provided.

6. The cab signal/ATC/ACSES system shall deduce that certain external failures have occurred and record these failures as well as internal failures.

7. The final configuration and definition of the cab signal/ATC/ACSES failure data recording system shall require acceptance by the Authority.

8. Access to the Failure Data Recording System shall be through the PTE as defined in Part T19.04C.

I. ACSES Portable Shop Test Set

1. The Contractor shall provide under this Contract, three (3) ACSES portable shop test sets that can test the functionality of the ACSES system, with the cab car in a static, shop environment.

a. For the purpose of this device, the MBTA defines “portable” as capable of being

transported and used by a single mechanic.

b. Five spare sets of software with licenses shall be provided on diskette or other Authority approved media shall be provided.

2. At a minimum, each ACSES portable test set shall be accompanied by the following:

a. One set of software with licenses shall be provided on diskette or other Authority approved media shall be provided.

b. One complete set of replacement cable and connector assemblies for the equipment provided.

c. A portable transponder, capable of simulating any and all wayside markers (passive and dynamic) necessary to statically test the functionality of the ACSES equipment.

d. Spare parts as recommended by the equipment supplier to repair any component failure in the test apparatus.

e. Any other equipment necessary to test the reception functionality of the ACSES system.

3. The Contractor shall also develop and submit for review and acceptance, the following:

a. A "User Manual" for the ACSES portable shop test set, which will be the basis for the maintenance training on this device. Six (6) copies of the approved manual shall be supplied.

b. Complete wiring diagrams, schematics, and maintenance and calibration instructions for the device itself, including circuit boards and microprocessors, if provided.

4. The Contractor shall thoroughly instruct the Authority's contract operator in the use of the portable ACSES shop test set as a part of formal training sessions.

10.02 FRA EVENT RECORDER SYSTEM

A. Each locomotive shall be equipped with a crashworthy event recorder system with integrated alerter that is fully compliant with the FRA requirements of CFR 49 Part 229. The event recorder shall be interchangeable with the event recorders installed in the Authorities HSP46 locomotives and/or 1800 series cab cars and overhauled 1700 series cab cars. The specified event recorder is Bach Simpson Model No. 54300 and the specified TMS alerter head is Bach Simpson Model NO. 54600. It shall be located in the short hood.

1. Should software upgrades to the PTE or event recorder software on the previously already delivered event recorders for the 1800 series cab, HSP46 locomotive, or overhauled 1700 series fleet be required, the Contractor shall provide the Authority a means to update the equipment such that physically equivalent hardware

B. The data collected, the equipment installation and playback software shall be approved by the Authority.

1. Two complete sets of office playback equipment shall be provided with the first

locomotive.

C. In addition to the signals that are required to be recorded by CFR 49 Part 229, at a minimum, the following, but not limited to, shall be recorded:

1. Time
2. Distance
3. Speed
4. Cab Signal Aspects
5. Cab Signal Territory
6. ATC Cut-In/Cut-Out
7. ACSES Cut-In/Cut-Out
8. ATC/ACSES Acknowledge
9. ATC Penalty
10. ACSES Penalty
11. Alerter Penalty
12. Throttle Position
13. Low Idle
14. Reverser Position
15. Brake Pipe Pressure
16. Brake Cylinder Pressure
17. Main Reservoir Pressure
18. Independent Brake Bail-OFF
19. Dynamic Brake
20. Tractive/Dynamic Brake Effort
21. Horn
22. Bell
23. Wheel Slip
24. PCS

25. "NOT" ACSES equipped

26. ACSES Overspeed

27. Headlights ON

28. Engine Run

D. The list of signals to monitor shall be provided to the Authority for review and approval.

E. The ERS shall provide a remote download location in the operating cab at a location that will be approved by the Authority.

F. The event recorder system shall also provide a horn sequencer function for grade crossings.

1. The sequence shall be, two LONG, one SHORT, and one LONG, blast from the horn

2. Whenever the horn is activated, the crossing bell shall also be activated.

3. The horn sequencer shall be triggered by a new HORN pushbutton on the Operator's desk console in a location to be approved by the Authority.

G. All existing Event Recorders shall be removed from the locomotives and returned to MBTA stores.

H. The scope of work includes all new wiring, piping, transducers, pressure switches, conduits required to add any additional analog or digital inputs and outputs to the new event recorder.

I. All existing transducers and pressure switches shall be renewed.

10.03 ALERTNESS / VIGILANCE CONTROL SYSTEM

A. General

1. Any existing alertness / vigilance control systems shall be replaced with an alertness system / vigilance control system integrated as a part of the FRA event recorder specified in **Part 10.02** and identical to that on the HSP46 locomotive and/or 1800 series cab cars and 1900 series cab cars.

2. A TMS control head, identical to that on the HSP46 locomotive or 1800 series cabs shall be installed to provide operator's indication of alertness status.

3. The installation arrangement of the Alertness/Vigilance Control System control head shall be subject to review and acceptance of the Authority.

B. Operation, Control, Acknowledgement Resets

1. The control, operation, and alertness reset settings for the Alertness and Vigilance Control system functions shall be equivalent to those provided by the Bach-Simpson Event Recorder and Alertness system installed in the HSP46 locomotives.

PART 11.00 – STYLING AND PAINTING

11.01 GENERAL

A. The interior and exterior of the locomotive shall be thoroughly cleaned and prepared for repainting in accordance with the requirements noted below, and in **Part 21.00**.

B. All painted surfaces shall be properly prepared, primed and painted to prevent corrosion and to maximize paint life.

1. The paint system used shall be compatible with all cleaning chemicals and procedures used by the Authority.

C. Decals and striping shall be edge sealed per manufacturer's instructions

1. Where decals cannot be used for striping, paint of correctly matching colors may be used.

D. Exterior signage and danger tags shall be applied in compliance with all applicable FRA regulations and APTA recommended practices.

E. Metal tags shall not be used to identify electrical components, except as reviewed and approved by the Authority. Plastic, self-adhering tags may be submitted for review and acceptance by the Engineer.

F. All electrical cabinet interiors shall be finished with white Glyptol or equal insulation paint or coating.

G. All coating materials shall meet all applicable State and Federal environmental, health and safety standards.

11.02 EXTERIOR PAINT SCHEME

A. The Contractor shall develop and submit three (3) exterior paint and styling schemes for Authority review and selection. Each scheme shall be submitted as a set of renderings of sufficient quantity and detail to represent the proposed appearance of the locomotive.

1. Renderings shall be submitted electronically in PDF, or other format accepted by the Engineer.

B. The exterior painting and styling scheme shall present a modern appearance that is distinct from the current scheme, but which will remain true to the MBTA's current purple, yellow and silver color scheme. Submitted schemes shall result in a cohesive appearance when the completed locomotives are operated together with the Authority's existing coaches. Exterior paint scheme shall be continuous with the same colors on the Authority's adjacent passenger cars. (see Figures G11A and G11B in **Appendix F**).

C. For the selected scheme, the Contractor shall prepare and submit for acceptance by the engineer, a detailed paint and styling diagram, indicating the application of all paint and decals. The diagram shall include both interior and exterior details.

D. A further revision of the selected scheme may be required after inspection of the first unit painted.

11.03 PAINT

A. Polyurethane paint shall be used on all exterior painted surfaces of the locomotive except for the fuel tank, air reservoirs, trucks, battery boxes, and other underfloor painted surfaces, which shall be enamel.

B. Interior paint shall be enamel.

C. Paints shall be DuPont "Imron" Polyurethane and "DuLux" enamel.

11.04 COLORS

A. Polyurethane paint colors shall match those on the Authority's HSP46 or other locomotives, subject to Engineer approval:

1. Silver (Aluminum): Imron 3.5 333MAG009
2. Purple: Imron 3.5 42-83U
3. Yellow: Imron 3.5 42-N0127
4. Black: Imron 3.5 333M24926
5. White Imron 3.5 LF632226P
6. Blue Imron 3.5 42-77257
7. Red Imron 3.5 426543

B. Enamel paint colors shall be as listed below or Engineer accepted equal:

1. Black: DuLux 93-005
2. Blue: DuLux 93-77257
3. Red: DuLux 93-6543 D
4. Beige: Alkyd 917-Y-12145

5. Brown: Alkyd 917-Y-12146

6. White Stenciling: Contractor's standard

11.05 EXTERIOR PAINTING

A. Exterior paint shall be applied as detailed in the accepted painting and styling diagram, required by **Part 11.02**.

B. Application methods shall be Engineer-approved and in accordance with the requirements of **Part 21.00**.

C. The following items shall be painted as described here, or as otherwise approved and directed by the Engineer:

1. Polyurethane Paint

a. Yellow

i. Full height of vertical handrails on both sides of the locomotive of the cab and engine compartment and at all other boarding ladders.

ii. Handle portion of uncoupler rod to bracket (remainder of rod and brackets to be black).

iii. Roof numbers (see Part 11.07B.1).

iv. Step treads on boarding ladders.

v. Operating handles on cut out cocks for: train line brake pipe, main reservoir pipe, and truck brake.

b. Black

i. Body sides, ends, and roof above upper color band.

ii. Switchman's ladders at each corner of the locomotive up to bottom of side sill, except treads (see **Part 11.05C.1.a.iv**).

iii. Ladders on both sides of locomotive up to bottom of side sill at cab and engine compartment, except treads (see **Part 11.05C.1.a.iv**).

iv. Air intake shutters, which shall be painted prior to their installation in the car body.

2. Enamel paints

a. Black

i. All under-carriage painted surfaces including pilots and MU control train line receptacle boxes and covers.

b. Blue

i. Communications train line receptacle boxes and covers.

c. Red

i. Auxiliary power (HEP) train line receptacle boxes and covers.

d. Contractor's standard acid resisting paint

i. Interior of battery boxes shall be protected with

3. Unpainted

a. Horns

4. Black anti-skid paint

a. An additional coating of black anti-skid paint (Mortell #3009 or approved equal) shall be applied to all walkways and platforms and to the top surface of the short hood (nose), subject to Engineer approval.

5. Reflective tape

a. An intermittent lie of horizontally oriented white reflective tape (Scotchlite or accepted equivalent) shall be applied to both side sills of each locomotive.

i. The location and length of the strips shall be subject to acceptance by the Engineer.

ii. Tape shall be high quality reflective type with repositionable (low initial tact) permanent adhesive backing which has been service proven for transportation applications.

11.06 INTERIOR PAINTING

A. The interior of the locomotive shall be painted as follows:

1. Cab short hood interior - Beige

2. Inertial filter compartment and items therein - Suede Gray

3. Remainder of long hood - Suede Gray

B. Interior equipment shall be color coded, and equipment designations shall be installed as directed by the Engineer.

1. Name plates on equipment cabinets shall be heavy duty aluminum or acrylic plates with white or aluminum letters in black background, arranged to provide optimum legibility in poor lighting conditions.

C. Control stand shall have a black, durable coating applied, such as powder coating or other

Engineer approved coating that is suitable for the application and environment. A finish that will minimize glare and distraction shall be proposed for review and acceptance by the Engineer. The proposal shall include a touch up procedure for the proposed coating.

11.07 NUMBERS, LOGOS AND PLATES

A. Contractor's paint schemes and detailed paint and styling diagram (see **Part 11.02**) shall include the markings described in this section, **11.07**.

1. See also Parts 6.02B, 6.04D and 17.04D.1.

B. Locomotive Numbers

1. Roof Number:

a. Roof number shall be 33 in. (838 mm) high yellow polyurethane

b. It shall be centered on the longitudinal center line over the cab with bottom of numbers to the rear of the locomotive.

2. Side Numbers:

a. Side numbers shall be 12 in. (305 mm) high yellow paint or yellow edged purple decals.

b. They shall be located approximately over the forward end of the rear truck frame on each side of the locomotive, in a location appropriate to the paint scheme, or in other location as directed.

c. Application of side, rear, and forward numbers shall be meet the application guidelines in Figure G6.

3. Rear Number:

a. Rear number shall be 6 in. (152 mm) high yellow vinyl

b. It shall be horizontal, centered vertically on upper black band and right side of locomotive when facing forward.

4. Forward Number Panels:

a. Forward number panels in illuminated number boxes are to be fiberglass with 6 in. (152.4 mm) high white numerals and black background.

b. One full set of spare panels shall be provided for stock.

c. Construction of number boards shall be submitted for review and approval by the Engineer.

5. Interior Cab Number:

a. Interior cab number shall be 3 in. (76.2 mm) high brown vinyl.

b. It shall be preceded by the brown letters XMBT and located on transom above windshield.

C. "F" Markings

1. “F” markings shall be black vinyl 5 in. (127 mm) high as shown in Figure G52 (**Appendix F**).

2. One “F” shall be located on the bottom, front end of each carbody side (two labels per unit).

D. MBTA Markings

1. MBTA Logo (T within circle):

a. MBTA logo shall be black and white vinyl 17 in. (559 mm) high as shown in Figure G20 (**Appendix F**).

b. Side Logos:

i. One logo shall be located on each side of the locomotive

ii. Each shall be horizontally centered approximately 9 ft. 5 in. (2.87 m) to rear of the front truck center line on each side of the locomotive, or other locations as directed. Vertical location shall be proposed by contractor for Engineer review, to be integrated with the proposed paint scheme.

c. Front Logo:

i. One logo shall be located on the front of the locomotive, located horizontally centered on the centerline of the locomotive. Vertical location shall be proposed by the Contractor for Engineer review, to be integrated with the proposed paint scheme.

2. MBTA Name Panel

a. The 16 in. (406 mm) square MBTA name panel shall be as shown on Figure G25 (**Appendix F**).

b. It shall be centered beneath road numbers on rear end.

3. Ownership Plates

a. Existing ownership plates on side sills shall be removed, repaired as required, and reinstalled.

E. Class Number

1. Class number shall be 1 in. (25.4 mm) high black vinyl characters

2. One 1 in. (25.4 mm) high class numbers and letters as shown in Figure G7 (**Appendix F**) shall be applied centered horizontally about the vertical centerline of the cab side

equipment access door with bottom of numbers 4 in. (25 mm) above top of hinge, (two sets per locomotive).

F. Model Numbers

1. Model numbers shall be 2 in. (50.8 mm) high yellow vinyl decal with black characters, per Figure G8.

2. One model number label decal shall be applied in a location centered under each cab side window (two decals per locomotive).

G. Cable Application Plate

1. Stainless steel etched plate as shown on Figure G65 (**Appendix F**) shall be applied to the No. 2 end plate, left side, below the uncoupling lever.

H. Equipment Identification

1. 0.75 in. high by 0.08 in. thick stainless steel plates with 0.25 in. high engraved letters filled with black paint and secured by stainless steel pop rivets shall be applied, as directed by the Engineer.

a. Existing end sheet plates, where suitable, may be cleaned and reapplied.

b. Side sill designations shall include, but not be limited to:

i. Brake pipe cut out

ii. Main reservoir pipe cut out

iii. Truck brake cut out

iv. Retention tank drain

v. HEP starting reservoir drain

I. Glazing Badge Plate

1. A badge plate as shown on Figure G80 (**Appendix F**) and in accordance with 49 CRF 223 shall be installed in the operating compartment.

J. Weight Plate

1. Weight of completed locomotive at No. 1 end truck, No. 2 end truck and total light weight (dry) to the nearest pound and date of weighing shall be provided on weight plate, as shown in Figure G70 (**Appendix F**).

K. Instruction Cards

1. Instructions on stainless steel plates shall be provided on each locomotive in the cab or long hood as directed by the Engineer.

L. American Flag:

1. American flags shall be 15.50”by 29.00”, vinyl decal, including ¼” white border

2. One flag decal shall be applied to each sides of the locomotive, towards the F-End.

3. The Union (blue field) shall face towards the F-End on both sides. The location shall be subject to acceptance by the Engineer.

4. The colors shall be the official colors:

a. Cable No. 70180 Old Glory Red

b. Cable No. 70001 White

c. Cable No. 70075 Old Glory Blue

M. Fonts

1. All letters and numbers shall be Helvetica Medium face as shown in Figure G1 (**Appendix F**).

a. Adobe Helvetica Bold is acceptable substitute.

b. Letter and number spacing shall be as shown in Figure G5 (Appendix F).

c. Road number application shall be as shown in Figure G6 (Appendix F).

N. Danger Sign

1. Where required, danger signs shall be as shown in Figure G60 (Appendix F).

11.08 REVIEW DRAWINGS

A. Contractor shall furnish to the Authority a minimum of sixty (60) days prior to painting of the first locomotive, four (4) copies of draft styling and painting diagrams showing all car body features such as doors, ribs, etc. which would affect the masking and painting of the locomotives.

B. The Authority will furnish one (1) copy showing required revisions, and the Contractor shall paint the first locomotive.

C. The Engineer will inspect the first locomotive after painting, at which time the application of the letters, numbers, logos, and plates shall be made, and revised as required.

D. The Contractor shall revise the painting diagram as required and shall resubmit for acceptance by the Engineer.

E. Further locomotives shall not be painted until the first unit arrangement is accepted by the Engineer.

11.09 PAINT SAMPLES

A. Contractor shall furnish to the Authority a minimum of two (2) sets of color samples showing all colors and finishes to be used on the locomotive.

B. Each sample shall consist of a 4 in. by 6 in. (102 x 152 mm) aluminum plate with one side covered completely with a single color and with reverse side provided with label showing manufacturer's name, color name, identification number, and paint type name.

C. A total of six (6) sets of samples of final accepted colors shall be furnished to the Authority prior to completion of locomotive delivery.

11.10 GRAPHICS SAMPLES

A. A total of two (2) sets of sample logos and plates shall be furnished to the Engineer for review and acceptance prior to manufacture of production materials.

B. Samples of each decal or sign to be applied to the locomotives shall be furnished to the Authority for review and Acceptance.

PART 12.00 – ELECTRICAL SYSTEM

12.01 MAIN GENERATOR

A. The main generators are EMD model AR10A-CA5 or AR10A-D14.

B. The AR10A-CA5 main generators shall be overhauled in accordance with the specifications of the original equipment manufacturer, and Authority Specification provided in **Appendix B**.

1. The AR10A-CA5 main generators existing on the locomotives must be overhauled and returned with the locomotives, except as specifically authorized otherwise by the Engineer.

C. The AR10A-D14 main generators shall be replaced with new or remanufactured AR10A-CA5.

12.02 COMPANION ALTERNATOR

A. The companion alternators, integral with the main generators, shall be overhauled in accordance with applicable EMD M.I.s and Authority Specification SR-39.

12.03 AUXILIARY GENERATOR

1. The auxiliary generator shall be overhauled in accordance with latest issue of:

a. EMD M.I. 3707 – AC Auxiliary Generator (Brushless Type).

12.04 HEAD END POWER

A. A separate diesel generator supplies head end power for the train.

1. This power is not used by the locomotive, except for layover heating, auxiliary charging of the locomotive battery, and locomotive cab HVAC unit.

a. For a description of head end power, see Part T7.00.

b. For a description of layover heating, see Part T8.00.

c. For a description of auxiliary battery charging, see Part T8.06.

d. For a description of the cab air conditioning unit, see Part T14.00.

12.05 LOCOMOTIVE CONTROL

A. The existing relay based locomotive control system shall be disconnected and removed.

B. A new computer control system as manufactured by EMD or approved equivalent shall be designed and installed as required. All existing components of the original relay system which are not required for the computer control system as well as associated wiring shall be disconnected and removed. The system shall provide improved adhesion, wheel spin/slide control and overall locomotive acceleration. The control functions of the computer control

system shall include, but not be limited to the following;

1. Excitation Control
2. Self-Load feature
3. Auxiliary Alternator Control
4. Power ramp-up control and throttle control
5. Propulsion control
6. Wheel Slip/Slide Control
7. Slow Speed Control
8. Engine cooling fan and shutter control
9. Load Meter Drive
10. Air Compressor control
11. Sand Control, automatic and operator initiated and for wheel slip control
    a. Emergency sand cut out at Vz
12. Engine Speed Control
13. High and Low Idle Control
14. Traction Motor Cutout and automatic power reduction where applicable
15. Dynamic Brake Cut - Out
16. Power contactor control
17. Low Voltage Power Supply (LVPS) and battery charging control
    a. Real time voltage/amperage display
18. Built-in diagnostics

C. Operator initiated locomotive tests to include, but not limited to: Contactor Test, Relay Test, Cooling Fan Test, Self -Load Test and complete test of all electronic plug-in cards and modules.

1. Real time display of input signals
2. Easy to use, color touch-screen display.
3. Alarm and/or fault archive save in Flash or battery-backed memory.

4. Multiple data packets stored with each fault.

5. Real-time statistical data accumulation to include: Miles, Hours in each Throttle, Total Hours, Total KW Hours

6. Stored data to be extracted by Laptop with USB, by removable memory card and via cellular network.

7. Auto Engine Stop/Starting (AESS)

D. Locomotive protection functions of the computer control system shall include, but not be limited to the following;

1. Main Generator/Alternator - over current, over voltage, over excitation.

2. Traction Motor – overcurrent, locked axle, slipped pinion, over speed, over temperature, motor stall

3. Ground Relay - Automatic Reset and Lockout

4. Main Engine – Hot engine power reduction and return to idle

5. Contactors – fail to open, fail to close

6. Aux Gen “circuit breaker open” alarm

7. Unpowered locked wheel detection

8. Control System - Faulty sensors, Low voltage, High voltage, Voltage transients

9. Wheel Slip indication and alarm, including MU operation.

E. The locomotive control system software shall comply with all CFR requirements.

F. Design criteria for the computer control system shall be as follows:

1. The installed components of the system must be accessible.

2. Circuit boards must be easily replaceable without special tools.

3. Trouble shooting and diagnostics must be easy to perform.

4. On-board diagnostic features must be easy to use and understand.

5. The extended diagnostic software must be user friendly

6. The existing electrical cabinet shall be reused.

G. High voltage circuits are protected by a ground protection system.

1. Ground fault, sensed as an imbalance of supply and return current, the threshold of which shall be set as necessary to avoid nuisance trips

H. Power contactors and the Reverser are electromagnetically operated.

1. Power contactors and the Reverser shall be renewed with OEM components, as noted in **Part 12.06**.

I. Unless approved by the Engineer, all circuit returns shall be through the same electrical system. That is, if the equipment or circuit is common to the locomotive (or car) and is fed from the locomotive (or car), then its circuit return shall be through the locomotive (or car)

J. In-line fuses, resistors, etc. are prohibited, unless approved by the Engineer.

K. The contractor shall provide dedicated power supplies wherever possible. The use of dropping resistors to correct for difference voltages is prohibited.

L. Suppression of transients shall be at the source of the transient.

12.06 ELECTRICAL CONTROL CABINETS

A. The main electrical control cabinets shall be removed from the locomotive and completely cleaned, remanufactured, rewired and tested as per OEM requirements.

1. The locomotive's diesel engine's control system shall be a microprocessor-based design (see **Section 12.05**) and the existing electrical cabinet shall be reused

B. At a minimum, the follow specific tasks shall be performed.

1. Replace air filter.

2. Replace door seals.

3. Renew all lock keepers.

4. All time delay devices shall be renew.

5. All name plates shall be renewed.

6. All sound insulation material shall be renewed.

7. The following components shall be replaced with new:

a. Power contactors

b. Dynamic brake contactors and switch gear motors

c. Motor braking contactors

d. Cooling fan contactors

e. Reverser switch gear and motor

8. All relays, diodes, pressure switches, indicator lights, switches, any contactor not listed in the previous paragraph (Item 7), and any other electrical devices not listed herein, shall

be renewed.

C. All panel wiring shall meet the recommendations of APTA RP-E-002.

D. All circuit breakers shall be sized per National Electric Code (NEC) requirements.

12.07 TRACTION MOTORS

A. The existing traction motors on the locomotives shall be overhauled or UTEX and returned with the locomotives, except as specifically authorized otherwise by the Engineer.

B. All traction motors shall conform to the following requirements.

1. The traction motors shall be overhauled in accordance with the specifications of the OEM, (EMD M.I. 3900, latest revision) and the Authority's Specification, which is attached as **Appendix C**.

2. Traction motors which cannot be overhauled to meet the above specifications shall be replaced with overhauled or UTEX motors as specifically approved by the Authority.

3. All pinions shall be qualified using OEM, or OEM approved, specifications.

4. The latest EMD motor lead glad-hands shall be applied.

5. New twin seal support bearings, EMD Part No. 9557789, shall be applied.

6. The commutator end bearing shall be replaced with "non-drop case" type if necessary.

   a. The axle play of that bearing shall be between 0.005 inches and 0.012 inches.

7. All new wicks and holders shall be installed, and secured with new "S" lock bolts.

8. All new traction motor dust guard assemblies shall be provided.

9. All Traction Motors shall be equipped with commutator covers with provisions for a speed sensor.

10. Traction motors shall be equipped with quick-access hinged inspection covers on top of motor only.

    a. Bottom inspection covers shall be bolt-on type.

12.08 BATTERY SYSTEM

A. Batteries

1. A new battery shall be provided by the Contractor.

2. The battery shall be a unitized LMUD 500 battery, except as specifically authorized otherwise by the Engineer.

3. Batteries shall meet the requirements of AAR RP-590 and APTA RP-E-007 and shall be

used to start the prime mover, provide power to lights and provide power to critical auxiliaries (e.g., radio and Cab Signal/ATC/PTC), while the locomotive is shutdown.

B. Battery Compartment

1. Battery compartment shall be cleaned, inspected, and repaired as required.

a. The compartment shall be fitted with ready-access cover or hatch, grating bottom, hold down devices and slides, and shall be adequately vented.

i. The Contractor shall install a new stainless steel grating bottom in place of present bottom panel

ii. The compartment shall be easily accessible for inspection and maintenance by providing for slide out of the battery and tray utilizing Barnes "SLIM-TRACK" or Engineer approved equivalent heavy duty stainless steel slides.

iii. The compartment shall be properly fastened to ensure that the battery is secured during any unsafe situation.

b. Battery compartment shall be arranged to drain clear of all underbody equipment.

c. The interior shall be repainted with a corrosion resistant paint.

d. The exterior shall be repainted in accordance with Part **11.00**.

C. Battery Charging

1. A locomotive-type, solid-state charger or approved equal shall be provided. An on-screen ammeter shall be provided as part of the locomotive control system in the Engineer's cab or another location approved by the Engineer.

2. Contractor shall provide a layover charger with a 480 VAC input to the battery charger (see **Part 8.00**).

12.09 DYNAMIC BRAKE

A. A blended dynamic brake / air brake feature is provided.

1. This system automatically calls for the proper mixture of air and dynamic braking with the operator required to use no control other than the automatic brake valve on the locomotive or control trailer car to effect such braking.

a. A Blended Brake CUT-OUT switch is installed to enable operation in conventional air mode. This Cut-Out switch can be removed if provided by the locomotive control system (see **Section 12.05**).

2. Dynamic brake is available only when the throttle handle is in the IDLE position.

3. Provision for automatic reset of dynamic brake at speeds below five (5) mph shall be made.

4. Traction power is available between zero (0) and five (5) MPH.

5. Braking levels shall be commensurate with safe operation of propulsion power and air brake systems.

6. Dynamic brake failure indication is to be available by illuminating the BLENDED BRAKE LOCKOUT indicator in the Engine Control panel.

B. Self-Load Test Feature

1. A self-loading feature shall be provided as part of the locomotive control system, the dynamic braking grids will be used to self-load the prime mover.

C. The dynamic brake grids shall be cleaned, inspected, tested, and rehabilitated per OEM requirements, or UTEX per latest issue of:

1. EMD M.I. 4104 – Dynamic Brake Grid Fan and Motor

D. The dynamic brake blower motor shall be cleaned, inspected, tested, and rehabilitated per OEM requirements, or UTEX per latest issue of:

1. EMD M.I. 4104 – Dynamic Brake Grid Fan and Motor

E. Push-to-test indicator lights shall be standard on the locomotive control stand, and on the engine control panel.

F. A new alarm buzzer shall be provided to indicate wheel slip.

G. The spare fuse rack shall have all new fuses applied, including two (2) spare 400 amp starting fuses.

H. Six (6) spare radiator blower motor fuses shall be provided in a readily accessible location, as approved by the Engineer, in the event that the fuses have to be utilized.

I. Fuel pump, soakback pump and all circulating pumps in the layover heating system shall have individual circuit protection.

J. All other electrical apparatus not otherwise specified shall be cleaned, inspected, tested, and repaired or replaced as required.

K. A 74 VDC-120VAC inverter, with sufficient capacity to supply the required 120VAC auxiliaries shall be provided.

1. Transformer installation brackets shall be designed to withstand 8g loads. Design and installation details shall be submitted to the engineer for approval.

2. The transformer shall be installed at an Engineer's approved location.

L. Duplex convenience outlets, 120VAC GFCI, 20 ampere, meeting the requirements of Section 4.6 in APTA SS-E-005, shall be installed in the locomotive.

1. The outlets shall have a spring loaded, water resistant cover over each plug receptacle.

2. There shall be a total of four (4) outlets installed on the locomotive, at locations approved by the Engineer.

    a. One (1) at the Control Stand

    b. One (1) within the Electrical Locker.

    c. One (1) outside the Electrical Locker

    d. One (1) within the HEP compartment.

3. The Contractor shall install, in a water-proof housing, a convenience outlet, with "male" contacts, on the exterior of the locomotive so that 120VAC shop power can be plugged into the locomotive to light the Locomotive's interior lights.

M. A separate power supply shall be provided in lieu of dropping resistors for both marker light and head light circuits.

12.10 WIRING

A. All locomotive wiring shall be renewed with low smoke, irradiated, cross-linked polyolefin wire (XLPO), in accordance with **Part 21.00**, except where otherwise specifically noted.

1. For wires and cables installed within electrical cabinets or enclosures, which are part of the locomotive construction, the Contractor may use an Engineer's Approved wire manufacturer's thin-wall insulation (nominal 15mils) thickness product, such as General Cable's Polyrad ULTRA or Rockbestos' EXANE 15.

2. All single conductor trainline wires, (27pt and HEP) shall have a minimum nominal insulation wall thickness of 30mils.

B. All wiring shall be installed and marked in the same manner as the wiring being replaced.

C. Wherever possible, all wiring shall be bench assembled in harnesses before installation.

1. Method of installation shall be arranged so as to avoid damage to the wiring by nicking or stretching.

D. All wiring shall be megger and high-potential ground insulation tested after installation.

1. See Part 19.00 for detailed testing requirements.

E. Head End Power cabling shall be run on the underside of the underframe, and not in raceways.

F. Microprocessor systems shall include protection against spikes and surges.

G. Modifications to the locomotive wiring and cable during the rehabilitation shall include removal of supplanted wiring.

12.11 CONTROL STAND

A. The control stand shall be removed, cleaned, stripped and repainted, rewired, and all components shall be renewed.

1. See Part 3.10 for further requirements.

12.12 ENGINE CONTROL (ISOLATION) PANEL

A. The engine control panel shall be removed, cleaned, stripped and repainted, rewired, and all components shall be renewed and updated to function with the new locomotive control system.

1. All name plates shall be renewed.

12.13 BODY END DOOR RELEASE TRAINLINE

A. A relay is provided to energize "Body End Door Release Trainline", MU control trainline 26.

1. "Body End Door Release Trainline" is powered by "Battery Positive", Communication Trainline 13.

2. "Body End Door Release Trainline" is energized whenever the locomotive is above Vzero.

3. "Body End Door Release Trainline" relay is EMD Part No. 8363168.

4. "Body End Door Release Trainline" relay is mounted in the electric cabinet.

B. System shall be requalified.

PART 13.00 – TRAIN LINES

13.01 GENERAL

A. Locomotives are capable of multiple unit operation in consists with all existing MBTA locomotives, and control and blind trailer coaches.

B. All train line receptacle and jumper components shall conform to their applicable sections of APTA RP-E-017, 018, and 019.

13.02 JUMPER CABLES

A. The following cables are used with each locomotive and shall be delivered new with each overhauled locomotive.

1. Two (2) 27-point locomotive control jumper cables 69 in. (1.75m) long Pyle-National WWPCJ-2755-S658 or approved equal.

    a. Cable heads are color coded black.

    b. The following wire crossovers are made in the cables: 8 and 9.

2. Two (2) 27-point communications jumper cables 69 in. (1.75 m) long Pyle-National WWPCJ-2755-S660 or approved equal.

    a. Cable heads are color coded medium blue.

    b. Twisted pair shields shall be terminated onto Pin 1 at only one end of the jumper.

    c. The following wire crossovers are made within the cables: 14 and 15, 16 and 17, 18 and 23.

3. Four (4) three-phase power jumper cables 53 in. (1.35 m) long having an AWG No. 4/0 min. size conductor per phase, and three (3) AWG No. 12 control wires, Pyle-National assembly No. P-208301-L53-S665 or approved equal.

    a. Cables are banded red.

B. Storage racks presently provided in the long hood for all jumper cables shall be refurbished.

13.03 RECEPTACLES

A. All existing 27pt (MU & COMM) and HEP receptacle assemblies shall be replaced with new.

B. The plate to which the new receptacles mount (27pt MU & COMM and HEP) shall be reinforced to resist, without deformation, forces produced from pulling the locked jumper out of the receptacle under all conditions. Portable jumper cables shall be sacrificial relative to the carbody mounted components under train partings or uncoupling.

C. Two (2) 27-point Pyle-National WWRF-27K or approved equal, locomotive control receptacles are to be provided at each end of the locomotive.

1. Receptacles are color coded black and marked with 1 in. (25.4 mm) white letters "MU".

2. Locomotive control train line receptacle pin assignments are as listed in Figure 13-1.

D. Two (2) 27-point Pyle-National WWRF-27-AMTR or approved equal, communications train line receptacles are provided at each end of the locomotive.

1. Receptacles are color coded medium blue and marked with the 1 in. (25.4) white letters "COMM".

2. Communication train line receptacle pin assignments are as listed in Figure 13-2.

E. Four (4) 3/3 pole head-end power receptacles are provided at each end of the locomotive.

1. When facing each pair of receptacles at the No. 1 end of the locomotive, both the left and the right hand receptacles are Pyle-National No. RPC-17-96 or approved equal.

2. When facing each pair of receptacles at the No. 2 end of the locomotive, the left hand receptacle is Pyle-National No. ZRCP-C24-72P or approved equal, and the right-hand receptacle is Pyle-National No. RPC-17-96 or approved equal).

a. ZRCP receptacles shall be environmentally protected using potting sleeve, Pyle-National No. ZP-8224-11; insert clamp nut, Pyle-National No. ZP-W-7524-B, and Engineer accepted potting compound

b. Right hand receptacles shall be renewed with Pyle-National No. RPC-17-420 or approved equal receptacles.

3. The left hand receptacles at the B-end (threaded type) are mounted so that the alignment notches are at the 12 o' clock and 3 o' clock positions.

4. 4/0 wire pigtails from the train line receptacles shall be spliced into the locomotive train line wiring behind the end plate using an AMPOWER, two bolt mechanical connection covered with two (2) layers of RAYCHEM dual wall heat shrink tubing.

5. Warning and identification of head-end power receptacles provided on each end of the locomotive shall be renewed.

6. Simplified instructions for connecting, disconnecting, and storing of jumpers, including safety precautions provided at the B-end left side end plate of the locomotive shall be renewed.

7. Receptacles shall be color coded bright red.

13.04 HEAD END POWER TRAIN LINE

A. Existing head-end power train line cables and wire shall be renewed and tested in accordance with all of Part 12.10and Part 19.04B.

B. Head end power trainline shall conform to all recommendations and requirements for a single buss HEP systems defined in APTA RP-E-016, except as specified herein.

C. Phase sequence shall be L1, L2, L3 (counterclockwise) as viewed looking into the right hand male receptacle in each pair.

D. Existing electrical control and components for isolating the 480VAC contacts at the F-end HEP receptacles shall be renewed.

13.05 AIR END CONNECTIONS

A. Locomotive MU air connections

1. Actuating and independent equalizing connections are provided at each end of the locomotive and on both sides of coupler.

2. All existing hoses and dummy couplings shall be removed and discarded.

a. Identification metal name plates shall be renewed.

b. Four (4) each actuating and independent equalizing connect ports shall be equipped with new Aeroquip male quick disconnect fittings.

c. Four (4) each actuating and independent equalizing hoses shall be equipped with new Aeroquip female quick disconnect fittings, Westinghouse Air Brake 543006, and have a length of 35.625 in. (905 mm).

d. The above quantities cover one complete locomotive application.

3. MU hoses shall be stored and shipped in the hose rack provided in the long hood of the locomotive.

a. Hoses shall be less than one (1) year old from date of manufacture at time of pre-shipment inspection.

B. Train line air connections

1. All new hoses shall be installed.

a. The brake pipe hoses to be provided shall be 1.375 in. x 22 in. (35 mm x 559 mm) with FP-5 couplings and 1.25 IPS nipple.

b. Brake pipe train line hose connections shall be in accordance with AAR Specification M-601, latest revision, less than one year (1) old from date of manufacture at time of pre-shipment inspection.

c. The main reservoir equalizing pipe hoses to be provided shall be 1.25 in. x 25 in. (29 mm x 635 mm) with LS-4 couplings Aeroequip No. 1531-16.

d. Main reservoir equalizing train line connections and any other air system hoses shall be wire reinforced type in accordance with AAR Specification M-618, latest revision, less than one (1) year old from date of manufacture at time of pre-shipment inspection.

i. At both ends of the locomotive the brake pipe and main reservoir equalizing hoses shall be provided with new supporting chains connecting the hose couplings with the underside of coupler.

ii. The chains shall be applied to insure that a minimum three (3) inch clearance is maintained between the couplings and the plane of the top of the running rails.

2. New Identification nameplates shall be applied to the side sill adjacent to the brake pipe and main reservoir equalizing pipe cutout cocks per **Part 11.07H**.

3. New dummy hose couplings and chains shall be provided at both ends of the locomotive for all hoses.

13.06 TESTING

A. All low and high voltage train lines shall be megger and high potential tested (refer to **Part 19.04B**).

Figure 13-1: Locomotive Control Train Line Pin Assignments, Wire Markers, and Wire Sizes

Pin		Function	Marker	Size Awg. No.
No. 1 End	No. 2 End			
1	1	Dynamic Brake Reset	DB1	12
2	2	Alarm Bell and Attendant Call	SG	12
3	3	Engine Speed D	DV	12
4	4	Negative	N	10
5	5	Automatic Emergency Brake Sand	ES	12
6	6	Generator Field	GF	12
7	7	Engine Speed C	CV	12
9	8	Car Forward	FO	12
8	9	Car Reverse	RE	12
10	10	Wheel Slip	WS	12
11	11	Dynamic Brake Fault	DB2	12
12	12	Engine Speed B	BV	12
13	13	Positive Control	PC	10
14	14	Spare (Future car TE Load meter)	SP1	12
15	15	Engine Speed A	AV	12
16	16	Engine Run	ER	12
17	17	Emergency Brake Magnet Valve	EB	12
18	18	Brake Application (Service) Magnet Valve	EP1	12
19	19	Brake Release Magnet Valve	EP2	12
20	20	Brake Negative	EP3	12
21	21	Spare	SP2	12
22	22	Spare (Compressor Control)	CC	12
23	23	Sand Control	SC	12
24	24	Spare	SP3	12
25	25	Headlight Control	XB	10
26	26	Body End Door Release	DU	12
27	27	Spare (Future car TE Load meter)	SP4	12

Figure 13-2: Communication Train Line Pin Assignments, Wire Markers, and Wire Sizes

Pin		Function	Marker	Size Awg. No.
No. 1 End	No. 2 End			
1	1	Communication Wire Shield	-	-
2	2	Battery Negative (Car)	TBN	10
3	3	Public Address	PA1	14 Shld.
4	4	Public Address	PA2	14 Shld.
5	5	Intercom	PA3	14 Shld.
6	6	Intercom	PA4	14 Shld.
7	7	P.A. Control	PA5	14 Shld.
8	8	P.A. Control	PA6	14 Shld.
9	9	PEI Control	RA 1 (PA7)	14 Shld
10	10	PEI Control	RA 2 (PA8)	14 Shld.
11	11	Door Interlock	SP5	12
12	12	Door Control (Spare)	SP6	12
13	13	Battery Positive (Car)	BP	10
15	14	Door Control Close Right	D1	12
14	15	Door Control Close Left	D2	12
17	16	Door Control Open Right	D3	12
16	17	Door Control Open Left	D4	12
23	18	Operator’s Doors Closed Light Left	DC1	12
19	19	Operator's Brake Release Light	BR	12
20	20	Operator's Brake Applied Light	BA	12
21	21	Hot Journal Light (Spare)	HJ	12
22	22	Communicating Signal	CS	12
18	23	Operator’s Doors Closed Light Right	DC2	12
24	24	PA/IC Control RS485	PA9	14 Shld.
25	25	PA/IC Control RS485	PA10	14 Shld.
26	26	Spare	BLS	12
27	27	Attendant Call (Spare)	AN	12

PART 14.00 – ROOF MOUNTED AIR CONDITIONING SYSTEM

14.01 NEW AIR CONDITIONING SYSTEM

A. Each locomotive shall be fitted with a single thermostatic control unit providing ventilation and air conditioning.

B. The unit shall be mounted into the cab roof.

1. The installed unit shall provide an interior finished cab height of 72 inches.

2. The unit shall fit within the existing contour of the locomotive and have no impact to the dynamic envelope.

3. All components shall be corrosion proof and compliant to 49 CFR 238.

4. The area around the unit and any ducting shall be insulated.

5. The cab ceiling shall enclose the unit and provide an aesthetic appearance.

6. Aesthetic covers will be provided, if required, to provide a clean exterior appearance. If the unit is exposed, it shall blend with the colors of the surrounding locomotive structure.

C. The unit shall be powered by the 480 volt, 3 phase, 60 hertz HEP unit and designed to achieve the following:

1. Sized to maintain the area around the crew comfortably cool under warm, hot, and humid weather conditions, maintaining a temperature no greater than 75 degrees F at external ambient temperature of 106°FDB, 73°FWB, at up to maximum forward speed.

D. Control Requirements

1. A fresh air thermostat shall lock out cooling at 52°F to protect the compressor from operation at low temperature.

E. Air Conditioning Components

1. All motors shall be powered from the 480 volt 3 phase HEP.

2. The unit shall utilize R-407C refrigerant and polyolester (POE) oil.

a. Condenser fan shall include a safety grille.

F. Electrical Interface

1. All electrical components within the unit shall be mounted in an enclosure in a location easily accessible for maintenance within the cab.

2. All electrical connections between unit and vehicle shall be through approved connectors.

3. A safety ground strap shall be provided between unit and carbody.

G. Unit Removal, Storage and Replacement:

1. The unit shall be designed to be easily installed and removed with the use of guiding fins or tubes that ensure the unit is properly located. Flexible return and supply air ducting will be aligned to engage with the unit when it is installed and disengage when it is removed. Ducting shall meet the smoke flame and toxicity requirements of 49 CFR 238.

2. The unit will be fastened in place with easily accessible hardware.

3. Removal and replacement maintenance shall be demonstrated, subject to approval by the Authority

4. Two (2) heavy duty welded steel trucks shall be provided with the first overhauled locomotive, each fitted with roller bearing casters, arranged to safely support the underside of an AC unit after removal from the locomotive during movement and repair activity in the shop, with design to be submitted to and approved by the Engineer.

14.02 ADDITIONAL HEATING AND VENTILATION COMPONENTS

A. Cab strip heaters are provided along the floor on either side of the cab, and are powered from the auxiliary generator (Refer to **Part 3.03**).

B. A separate heater powered from a single phase of HEP trainline is provided to heat the cab as part of the layover protection system (Refer to **Part 3.03A** and **8.03B**).

C. Separate fresh air ventilation shall be provided in cab side walls using new Salem 626 ventilators.

PART 15.00 – LIGHTING

15.01 LIGHTS

A. All lighting switches, dimmers, lamp holders, and fixtures that are not replaced during the overhaul of the locomotive shall be cleaned, inspected, tested, and repaired or replaced as required.

B. All existing interior and exterior light assemblies shall be removed and replaced with LED light assemblies.

1. LED fixtures shall have wiring connectors or "snap-in" features to facilitate ease of removal without the use of special tools.

2. LED fixtures shall have over-temperature protection with automatic reset.

3. LED drivers shall withstand voltage fluctuations and shall not be damaged by the intermittent or continuous application of the reverse polarity DC power.

4. Control of LED currents shall not cause any noticeable light flickering

5. Failure of a single LED shall not turn off the LED board and shall not reduce the life expectancy of the LED board

6. The expected service life of interior and exterior LED fixtures, shall be a minimum of 50,000 hours to 70% of original luminosity. Service life shall consider the operating environment for each fixture, including ambient temperature, engine room temperature, operating voltage, transient voltage, shock and vibration, etc.

7. The expected service life of LED headlights, ditch lights, and marker lights shall be a minimum of 25,000 hours.

C. Interior light fixtures in the operator's cab shall comply with 49 CFR 229.127.

D. Headlight fixtures shall be removed and replaced with LED light assemblies that meet the requirements of 49 CFR 229.125.

1. Headlight fixtures shall be designed for quick removal and replacement of headlamps. Headlight replacement shall require no more than 15 minutes and require no angular adjustment of the lamp.

2. Headlight fixtures shall be able to prevent light snow and ice buildup from forming on the lens.

E. Ditch light fixtures shall be removed and replaced with LED light assemblies that meet the requirements of 49 CFR 229.125 and 229.133.

1. Ditch light fixtures shall be designed for quick removal and replacement of lamps. Lamp replacement shall require no more than 15 minutes and require no angular adjustment of the lamp.

F. Ditch light controller shall be replaced to provide the same functionality as those on the

Authority's control cars and HSP46 locomotives:

1. Ditch lights shall function automatically (continuous) by the headlight switch when the headlights are in "BRIGHT" mode.

2. Ditch lights shall be extinguished when the headlight switch is placed in "DIM" mode.

3. Ditch lights shall function automatically (flashing) when bell and/or horn are activated. The flash rate of the ditch lights shall be between 40 and 180 flashes per minute. The final flash rate shall be reviewed for approval during design review.

    a. Ditch lights shall immediately stop "flashing" when the horn and/or bell are deactivated

4. Ditch light functionality shall be as approved by the Engineer.

G. Marker light fixtures shall be removed and replaced with LED light assemblies that meet the requirements of 49 CFR 221.

H. If lighting in the engine room and HEP compartment are not sufficiently illuminated with the existing light fixture layout, up to four (4) additional light fixtures shall be installed, with locations to be submitted for review and acceptance by the Engineer.

1. Additional light fixtures shall be wired to existing switches.

2. Fixtures and conduit, etc. shall match original construction.

PART 16.00 – COMMUNICATIONS

16.01 RADIO EQUIPMENT

A. The locomotives were originally equipped with Motorola 92 channel radios, which shall be removed prior to the locomotives being supplied to the Contractor.

B. The Contractor shall be responsible for inspecting, testing, and repairing as required all remaining portions of the radio system including the antenna, and all related wiring and cabling.

C. The Contractor shall provide a new radio. The Contractor shall propose a radio with features that meet or exceed those of the Motorola Spectra radio with external MIC option, 96 channels. The proposed radio shall be submitted for Engineer review and acceptance.

D. Radios shall be removed for shipping and reinstalled by Contractor for testing upon delivery.

16.02 PUBLIC ADDRESS/INTERCOM SYSTEM

A. Communication apparatus shall be replaced and provide the following services:

1. One-way communication from the train crew or operator to the passengers (Public Address System).

2. Two-way, private communication between the operator and train crew, and between members of the train crew (Intercommunication system).

3. Two-way, private communication between the passengers and the train crew (Passenger Emergency Intercommunication System).

B. The PA, IC, and PEI shall be controlled from a Communications Control Panel. This panel shall include the following.

1. A low profile, dynamic (noise canceling) microphone for PA/IC/PEI and a flush mounted IC/PEI speaker. Both shall be mounted behind a vandal-proof, perforated grille.

2. Three flush mounted, lighting, latching selector push buttons marked PEI, PA, and IC functions. These lights shall illuminate to show which function is selected.

3. Press-to-talk pushbutton switch with a “transmit” indicator light. The transmit indicator shall illuminate only when the microphone is active.

C. The PA/Intercom/PEI system shall be functionally compatible with the systems currently installed on MBTA locomotives and passenger cars.

D. The Contractor shall be responsible for testing compatibility between the overhauled locomotives and the Authority’s existing fleet.

16.03 HANDSETS

A. The contractor shall provide one new handset per locomotive for the operator's communication via radio, PA, IC, and PEI.

16.04 VIDEO RECORDING SYSTEM, FUEL LEVEL MONITORING

A. A Wi-Tronx digital video surveillance system, or approved equal shall be installed on each locomotive. The components included in the system shall be of the most current revision levels available, compatible with existing Wi-Tronix equipment installed on MBTA locomotives and at a minimum include:

1. Wi-PU Cell Detector
2. Wi-PU Install Kit, including antenna and shelf mounting bracket
3. Fuel Sensor Installation Kit
4. Fuel Display
5. WiPU to ZTR Smart Scan SCM Cable Assembly
6. WiPU to Event Recorder Cable Assembly
7. Ethernet Crossover Cable
8. Cell Detector Installation Kit
9. LDVR Installation Kit, including LDVR, Microphone, outward facing camera, and interior facing camera
10. ZTR SCM Module
11. Attention Assistant Installation Kit

B. The Contractor shall be responsible for installation of the equipment, including special tools and ancillary material required for the installation of the equipment.

C. The Contractor shall be responsible for performing commissioning and installation test at the conclusion of installation of the LDVR and WiTronix equipment.

D. A one year subscription shall be provided for Wi-Tracker and Wi-Download ER for each locomotive starting from the date of acceptance.

16.05 LOCOMOTIVE NUMBER / SEQUENCER

A. The Contractor shall install necessary electronics such that the locomotive transmits information to be used to display consist information in the cab control car and other equipped locomotives in the consist.

1. The locomotive shall include a module to transmit road number and dynamic brake effort information via the existing trainline communications network implemented on the Authority's HSP-46, Hyunda-Rotem Cab Cars, and Kawasaki Cab cars overhauled by Alstom which utilize equipment supplied by Quester Tangent.

2. The locomotive shall include a car bias circuit on a trainline to support vehicle sequencing.

3. Interface specifications, which shall allow the system to function, shall be provided by the MBTA.

4. The Contractor shall perform integration type testing with existing MBTA fleets to validate system operation.

PART 17.00 – AIR BRAKE SYSTEM AND AUXILIARIES

17.01 GENERAL

A. The locomotives are equipped with basic North American industry standard 26L locomotive air brake equipment with an overlay of electro-pneumatic (EP) control through train lined circuits which apply and release the brakes by means of magnet valves on each car which vent and recharge the brake pipe.

B. The normal operation of the brake system is from a locomotive or control trailer car equipped with a 30 AC DW or similar type brake valve control unit which exhausts or charges the brake pipe and simultaneously energizes "application" or "release" train line wires and activates the blended (dynamic and friction) brake feature.7

C. The brake system is so arranged that in the event of failure of any part of the electro-pneumatic control, including train line, the purely pneumatic brake pipe control function will be unaffected, and no further action on the part of the operator will be required for any braking function (release, service brake, or emergency brake application).

D. The brake system shall remain compatible for electro-pneumatic and pneumatic operation when used with conventional air brake equipment on any other existing MBTA commuter rail cars and when controlled from any existing MBTA locomotive or control trailer car, including MU operation of more than one locomotive.

E. This arrangement shall be maintained after the overhaul of the locomotive.

F. The brake schedule shall maintain the following features:

1. The provision for service application, including P2A valve and PC switch.

2. A-1 charging cutoff pilot valve, including two (2) No. 8 vent valves, controlling the following functions:

    a. Power knockdown from brake valve and / or A-1 charging cutoff pilot valve.

    b. Automatic thirty (30) second timed sanding from brake valve and / or A-1 charging cutoff pilot valve.

3. Main reservoir equalizing check valve.

4. Electro-pneumatic brake control, including change-end-protection, physically interchangeable, and functionally compatible with Wabtec (formally WABCO) CS-1 equipment.

    a. Contractor to repair or reinstall EP brake functionality and test.

5. MU2A valve.

6. Locomotive is equipped for push-pull operation and is able to send and receive EP brake signals.

G. Hand Brake

1. A new, electro-pneumatic hand brake unit shall be provided, installed and integrated into the locomotive to secure the locomotive when unoccupied. This system shall be capable of holding the locomotive with full supplies at rest on a 3% grade.

    a. The brake shall be activated and deactivated via an electric switch in the operating compartment. The switch shall be installed in a location to be approved by the Engineer.

2. A local "Hand Brake Applied" indication shall be provided.

3. An electric signal for "Locomotive Hand Brake Applied" shall also go to the BRAKE APPLIED trainline.

H. All parts and components in the entire air brake system that are not replaced new during the overhaul shall be cleaned – with rust, corrosion, and scale removed. They shall be inspected, overhauled, painted, and tested in accordance with the periodic, annual, and biennial tests required by 49 CFR 229.25, 229.27, 229.29, and 229.53.

1. This includes, but is not limited to hand brake, valves, valve portions, cut-out cocks, including related dirt collectors and filters.

2. All existing valves and cocks not replaced new during the overhaul shall be completely disassembled, cleaned, repaired, and painted per the manufacturer's instructions and procedures or replaced as required.

3. All components of a given function shall be identical throughout the group of 25 locomotive units.

    a. Odd components received with the locomotives shall be removed and replaced with standardized material.

    b. Odd components shall not be placed back on the locomotives as part of the overhaul process.

    c. The Contractor shall prepare a list describing all components by function, and listing standard part numbers for each function, for review and acceptance by the Engineer.

4. The EP brake system shall be qualified and certified to be functional to as-built specifications.

5. All air brake repair work shall be done at an AAR approved facility.

17.02 WHEEL SLIDE SYSTEM

A. Wheel slide protection shall be incorporated into the locomotive control system described in in **Part 12.05**.

17.03 AIR PIPING AND HOSES

A. All air piping shall be replaced to original as-built layout and with as-built specified

materials.

1. Missing pipe clamps shall be replaced.

B. Air piping shall be standardized on all locomotives including locations of reservoirs, valves, manifolds, and other air system components. Odd pipe layouts shall be removed and replaced with the standardized design.

C. The brake pipe shall be tested and verified for restriction and leakage in accordance with AAR and 49 CFR 238 requirements.

D. All copper lines and fittings shall be cleaned, repaired, or replaced as required.

E. Brake cylinder hoses shall be replaced with new AAR approved hoses of equal length and diameter.

F. Brake pipe and MU connection hoses shall be replaced with new AAR approved hoses of equal length and diameter.

17.04 CUT-OUT COCKS AND VALVES

A. Brake pipe angle cocks shall be replaced with threaded type WABCO "Dynaball" or Engineer approved equal with spring locking handles, and shall be properly secured to support brackets by means of one 5/8 inch U-bolt each after overhaul.

B. The location of all cut-out cocks shall remain readily accessible from the side of the locomotive after overhaul.

C. The cut out cocks for the MU hose connections (main reservoir equalizing, brake cylinder equalizing, and actuating) shall be maintained as automatic bleed-off type.

D. After overhaul, all cut out cocks in the air brake system, and auxiliary air operated systems, etc., shall be locking handle ball type.

1. Existing plate, EMD 9572655, shall be cleaned and repaired, or renewed.

17.05 AIR COMPRESSOR AND AIR DRYER

A. The existing air compressors shall be replaced with a new air compressor having the equivalent performance characteristics including a minimum 254 cubic ft./min. (7.2 cubic m/min) delivery at 900 RPM and 140 psig (965 kPa).

1. The new compressor shall be a reciprocating oil-lubricated type directly driven off the prime mover.

2. The compressor shall be equipped with a high efficiency dry-type intake filter.

3. Compressor low oil shutdown protection shall be provided.

4. Compressor oil filler plug shall have a provision for sealing.

5. The compressor drive shaft shall be dynamically balanced.

6. The compressor shall be fitted with an appropriate after-cooler circuit to lower the discharge air.

7. A service proven rotary screw compressor demonstrating the equivalent minimum performance may be proposed for Engineer consideration.

B. An electric air compressor governor shall be provided and adjusted to maintain reservoir pressure between 130 and 140 PSI (896 and 965 kPa).

1. All air compressor governor switches shall be new, with new switches complying with the requirements of 49 CFR 229.49.

2. A new dual contact pressure switch shall be provided for air compressor synchronization.

C. In the place of the present air dryer, a new twin tower desiccant air dryer shall be installed with the following features and configuration:

1. Coalescing filter to protect the desiccant media from oil contamination,

2. A blow-down timer with drain valve that expels coalesced liquids to the outside of the locomotive,

3. A memory feature that upon air compressor start-up, returns the dryer to the point in the dryer cycle which it was at when the air compressor shut down.

4. Physically interchangeable with a Salem 975-100 dryer, or approved by the Engineer

5. Shall be installed downstream of the No. 1 main reservoir.

D. Air delivered by the compressor, reservoir, and air dryer system into the locomotive trainline and auxiliary piping shall meet the requirements of APTA Standard SS-M-011-99 for temperature, dew point, and oil content.

E. A two-way cock, check valve, and additional air piping shall be provided to permit the complete air dryer system to be bypassed.

1. Following the bypassed circuit a Salem 975-075 air filter shall be installed.

2. The Contractor shall submit complete design details and calculations for the new air compressor and air dryer for Engineer review and approval (CDRL 17-02).

17.06 GAUGES AND FITTINGS

A. Gauges shall be replaced with new 4.5 in. (114.3 mm) Salem 7965-50 duplex gauges with black background.

B. Test fittings of an approved design shall be provided at all gauges.

C. Labeling of the gauge is to be on the console panel and not on the face of the gauge.

17.07 AIR RESERVOIRS

A. All reservoirs shall be cleaned and requalified or replaced with new of the same as-built size and configuration where required.

B. Reservoirs shall be drilled with 0.188 (4.8 mm) diameter tell-tale holes in compliance with 49 CFR 229.31.

C. Service proven automatic heated drain valves shall be provided on both No. 1 and No. 2 main reservoirs flange connections.

1. Suitable protection against debris damage for the drain valves and piping shall be provided.

2. Service proven blow-down timers with nominal three-minute cycles shall be provided for drain protection.

D. The J-1 Safety valve set at 150 psi (1034 kPa) shall be overhauled in accordance with the manufacturer's instructions and tested to comply with the requirements of 49 CFR 229.49.

E. An Engineer approved check valve shall be provided in the main reservoir trainline for break-in-two protection.

F. Control and equalizing reservoirs shall be inspected and tested in accordance with 49 CFR 229.31.

1. Failed reservoirs shall be replaced with Engineer approved replacement.

2. Following successful testing, reservoirs shall be primed, painted, and stenciled.

G. See Part 20.03C.2 for certification requirements.

17.08 WARNING DEVICES

A. Horn

1. Locomotives are equipped with five (5) chime Nathan K5LA, Dwg. WH-30171-5 air horns, facing the front of the locomotive, meeting the requirements of 49 CFR 229.31.

a. Horns shall be removed, cleaned, inspected, and refurbished in accordance with the manufacturer's instructions, tested and repaired or replaced.

i. New stainless steel snow cones shall be installed.

b. Horn valves and connecting tubing shall be cleaned, tested, and repaired or replaced.

c. Missing Horns shall be replaced with new.

B. Bell

1. The Contractor shall replace the standard locomotive bell with an electronic bell, such as Graham-White Series e-Bell, Salem electronic or other Authority Approved Equal, which duplicates the functionality of the pneumatic bell and carbody valves shall be removed.

2. The Contractor shall provide a new separate circuit and circuit breaker, as well as any necessary wiring and controls.

3. The electronic bell and its installation shall be submitted to the Engineer for review and acceptance. [CDRL]

4. The Contractor shall remove carbody piping and valves.

5. The Contractor shall return the removed bells to the Authority.

6. The bell switch shall be installed in a similar location on the control stand.

17.09 BRAKE CYLINDERS

A. All brake cylinders shall be replaced with new

B. Installed brake cylinders shall comply with the requirements of 49 CFR 229.55.

17.10 TESTING

A. After all overhaul work is completed, the complete air system performance shall be thoroughly tested to the satisfaction of the Engineer and in compliance with 49 CFR 229.46 through CFR 229.59.

PART 18.00 – DOOR CONTROL

18.01 GENERAL

A. The locomotive must work in consist with passenger cars equipped with power operated side doors and mechanically assisted body end doors.

B. Train Lines:

1. Locomotive control train line 26 and communication train lines 11, 12, 14, 15, 16, 17, 18, 19, and 23 are used to transmit control and indicating signals along the train (see **Figure 13-1** and **Figure 13-2**) including the locomotive.

C. Body End Doors – See Part 12.13

18.02 OVERHAUL

A. All components of the door control system on the locomotive must be inspected, tested, and repaired or replaced as required.

18.03 DOOR INTERLOCKS

A. Contractor shall modify the locomotives to be equipped with door interlock functionality.

B. The Locomotive shall have a 2 position Door Setup switch to configure the Door Interlock Train Line (11C). The positions shall be labeled “Lead/Thru” and “Trail”.

1. When the Switch is in the “Trail” Position 74 Volts shall be connected to the 11C trainline.

2. When the Door Setup Switch is in the “Lead/Thru” position, no voltage shall be applied to the 11C trainline from the locomotive.

C. A Door Interlock Relay shall be powered by the 11 C trainline when the Locomotive cab is the controlling cab of the train.

1. When the Door Interlock Relay is energized an indication that the doors are closed and locked shall be provided to the Engineer.

2. When the locomotive is set up to control the train and the train is moving above V zero speed, loss of energy on the 11C trainline shall cause loss of propulsion and a full service penalty brake application.

PART 19.00 – INSPECTIONS AND TESTS

19.01 GENERAL

A. Intent

1. It is the intent of this Specification that inspection of the locomotive and its components be the responsibility of the Contractor, and that inspection of the components be performed at the facilities of the sub-contractors so that corrections can be made under factory conditions.

2. The presence of the Authority's representatives at the facilities of the Contractor or of the subcontractors shall not in any manner supplant the Contractor's or subcontractor's own inspections or lessen the responsibility of the Contractor or subcontractor in respect to meeting all the requirements of the Specification.

B. Access

1. Authorized representatives of the Authority shall have access, at all reasonable times and as prearranged with the Contractor, to those parts of the facility of the Contractor or subcontractor for the purposes of inspecting materials and workmanship, processes, and of conformity to this Specification, during the progress of overhaul and assembly of the locomotive.

C. Authority's Inspections

1. The Authority in its continuing effort to assure that the locomotives be of the highest quality and in conformance with the Specification reserves the right to assign inspection personnel to witness all test procedures and to monitor the work on a daily basis.

   a. Authorized personnel will include the Engineer, the Consulting Engineer, and In-Plant Inspectors.

2. The Authority's participation in the Quality Assurance program is described in **Part 22.05**.

D. Inspection Costs

1. The costs of the Authority's inspection and compensation to Authority inspection personnel will be the responsibility of the Authority, and no provision for these costs shall be included in the bid prices.

E. Contractor's Quality Assurance

1. Part **22.00** describes the Contractor's responsibilities in providing and implementing a Quality Assurance Program.

F. Source Inspection

1. Material and/or apparatus which may be inspected at the source of manufacture or repair by the Authority's representatives includes but is not limited to the following items:

a. Prime Mover and Accessories

b. Main Alternator

c. Auxiliary Generator

d. Head End Power Unit

e. HEP Cabinets

f. Traction Motors

g. Electrical Control

h. HVAC Unit

i. Air Brake, Dynamic Brake, and Hand Brake Equipment

j. Wheels, Axles, and Mounting

k. Journal Bearings

l. Couplers and Draft Gear

m. Seats

n. Battery Charger

o. Pilot Locomotive

2. None of the foregoing material and/or parts shall be installed on the locomotives unless inspection has been performed by the Authority or waiver of inspection has been given to the Contractor in writing by the Authority.

G. First Article Inspection

1. Material and/or apparatus shall be inspected at the source of manufacture or overhaul by the Authority's representatives as may be deemed necessary by the Engineer.

2. The Contractor shall be responsible for notifying the Engineer and obtaining the Engineer's acceptance of the First Article sample, and of the method of its application prior to manufacture of subsequent articles.

a. Material acquired and installed prior to receiving First Article acceptance shall be done strictly at the Contractor's risk.

3. The Contractor shall provide on a regular basis a schedule of upcoming FAIs so that the Authority may dispatch suitable personnel.

a. Seven working days' notice must be provided for each FAI as finally scheduled.

b. If wrong dates are given or the Contractor is not prepared for inspection after

notification is given, then the Authority can and may recover from the Contractor any such costs involved in sending Authority personnel to the inspection sites.

H. General Test Requirements

1. All in-plant tests shall be performed at the Contractor's facility.

2. Use of track testing on a Railroad other than that described specifically herein is to be held to a minimum.

   a. After receipt of the locomotive at the designated delivery point and before passing into regular operation, each locomotive will be carefully inspected and any part, device, or apparatus requiring adjustment, repair, or replacement will be called to the attention of the Contractor in writing, who shall make adjustment, repair, or replacement at their own expense.

   b. The Authority will make available to the Contractor suitable level track of proper length and alignment within 100 miles of Boston, Mass., or other suburban terminal, to permit implementation of any non-revenue road tests that may be requested by the Contractor, or required by the Authority.

   c. All working and moving parts and all operating devices and controls of each locomotive and its apparatus shall be tested and put in proper operating condition by the Contractor at their plant before being presented for testing and acceptance by the Engineer.

   d. The Contractor shall perform all of the adjustments specified herein.

   e. It is anticipated that all road tests of the overhauled pilot locomotives will be completed within one (1) month and road tests of production locomotives will be completed within two (2) weeks of receipt of each locomotive at an acceptable Authority location within 100 miles of Boston.

   f. Road tests on individual locomotives will be conducted while in one or more train consists of new and/or existing cars when in revenue or non-revenue service.

      i. One or more days of static testing may be required prior to road testing.

   g. Train, crew and mechanical employee charges for non-revenue road and static testing will be the responsibility of the Contractor.

      i. The anticipated railroad costs for road testing will be $3000 per twelve (12) hour day.

   h. The Authority reserves the right to make, at its own expense, additional operating tests of locomotives as part of a revenue train consist or as a single locomotive.

   i. The Contractor shall assign a competent representative to witness such operating tests.

   j. Any defects disclosed by such tests, in apparatus, material, or workmanship shall be corrected promptly at the Contractor's expense and retested at the Authority’s

direction.

k. Due to regular maintenance demands on Authority facilities and on the Authority's Operating Contractor's maintenance personnel, it will be possible to undertake only minimal adjustment, repair, or replacement, work on equipment prior to Final Acceptance.

l. All expense and costs incurred in the removal/re-delivery of locomotives from/to the designated delivery point for correction of defects shall be borne by the Contractor.

I. Written Reports

1. Written or computer generated reports of all tests performed on the locomotives and their components shall be submitted to the Engineer.

a. Sample reports shall be submitted to the Authority for approval.

2. Tests required by the Specification which are performed on all locomotives or on all components shall be included in the Vehicle History Books described in **Part 24.01D**.

3. Reports on all tests of the one (1) per locomotive variety, such as road brake test, shall be submitted prior to final acceptance of the first locomotive and be included in the Vehicle History Book of the locomotive.

19.02 MASTER TEST PLAN

A. The Contractor shall prepare and submit to the Engineer for review and acceptance a Master Test Plan. It shall be the Contractor's responsibility to prepare the test plan, which includes all necessary testing to prove compliance with all requirements of this specification.

B. All tests included in this specification shall be included in the Master Test Plan, but the plan shall not be limited to the tests specifically called for in this specification.

C. The Master Test Plan shall include all supplier and sub-contractor tests to be completed at their respective facilities, all Contractor tests to be completed at Contractor's facility up to and including the Release for Shipment inspection, and all inspection and testing to be done on MBTA property.

D. The Master Test Plan shall be submitted to the Engineer for review and acceptance no later than sixty (60) calendar days after Notice-to-Proceed.

E. Test categories to be included in the Master Test Plan shall include, but not be limited to, the following categories:

1. Qualification Testing

2. First Article Inspection Testing

3. In-Process Testing and Inspections

4. Pre-Shipment Inspection

5. Receiving Inspection

6. Qualification Testing – one (1) pilot type

7. Commissioning and Acceptance Testing – all locomotives

F. At a minimum, the Master Test Plan shall contain the following information:

1. System, component and manufacturer of material being tested

2. Type of test (e.g. Qualification, Acceptance, etc.)

3. Location of testing

4. Scheduled Test Date

5. Scheduled Test Duration

6. Scheduled Attendees

G. The Contractor must notify the Engineer of any changes to the Test Schedule included in the approved Master Test Plan a minimum of fourteen (14) days before the affected test's scheduled date.

19.03 TEST PROCEDURES

A. All tests shall be performed in accordance with approved test procedures. Each test procedure shall include all information necessary to ensure the successful, accurate and safe performance of the described test. At a minimum, this shall include:

1. Safety precautions

2. Identification of the specification section(s) that are verified by the test

3. Scope and objectives of the test

4. Quantity to be tested

5. Test equipment required (including model number)

6. Personnel required

7. Any special conditions required, including condition of the equipment under test

8. Location of the test

9. Reference drawings or documents

10. Clear, step-by-step instructions for performing the test and any required set up of equipment.

11. Clear pass/fail criteria, including applicable tolerances, non-conformance correction

criteria, and retest provisions.

12. Data sheet to record test results, including confirmation of test equipment certification.

13. Procedures for correlating raw data to test criteria and pass/fail criteria.

14. Sample test report format.

B. Test procedures shall be prepared by the Contractor and submitted to the Engineer for review and acceptance at least 30 days prior to testing.

C. Test procedures must be accepted by the Engineer prior to use in testing.

D. Tests procedures shall include equipment and processes necessary to verify that the overhauled components and locomotives are in compliance with this specification any regulatory requirements, industry recommendations and best practices, unless otherwise directed by the Engineer.

E. Procedures for tests to be performed prior to completion of systems, components or vehicles (such as inbound functional tests) shall include sufficient detail in processes, equipment and data recording to accurately and consistently quantify the condition of the component, system or vehicle. The information gathered by these tests will be utilized in the development of processes and procedures for the repair/overhaul program.

19.04 INSPECTIONS AND TESTS

Inspections and tests shall include, but not be limited to the following:

A. In-Process Inspections and Tests

1. In-process inspections and tests shall be performed by the Contractor and witnessed by the Authority's representatives.

   a. The Contractor shall make every reasonable effort to notify the Authority's representative of dates and times of in-process inspections and tests.

2. Testing shall be done in the Contractor's facility before overhaul work, during the overhaul process, and after all work is completed.

   a. Testing before overhaul work shall be done to determine the condition of existing equipment and the overhaul work to be accomplished, and shall include, but not be limited to, water tightness and electrical system integrity.

   b. Testing during the overhaul process shall be done to ensure the quality of replacement parts and the correctness of their installation.

   c. Final testing after all overhaul work is completed shall be done to ensure that the locomotive and all its interrelated systems are operating correctly and efficiently, and that the locomotive is ready for revenue service.

3. In-process tests shall be performed in accordance with procedures prepared by the Contractor and accepted by the Authority and shall include, but not be limited to, the

following:

a. Diesel Engine Prime Mover - all locomotives

b. Traction Alternator - all locomotives

c. Companion Alternator - all locomotives

d. Traction Motors - all locomotives

e. Auxiliary Generator - all locomotives

f. Electrical Control Wiring - all locomotives

g. Prime Mover Load Test - all locomotives

h. Head-End Power Unit Test - all locomotives

i. Carbody Watertightness - all locomotives

j. Static Air Brake and Handbrake Tests - all locomotives

k. Locomotive Wiring - all locomotives

l. Trainlines - all locomotives

m. Communication System - all locomotives

n. Heating Functional Tests - all locomotives

o. Cooling Functional Tests – all locomotives

p. Weights by Truck - all locomotives

q. Head Lights - all locomotives

r. Marker Lights - all locomotives

s. Head-End Power Unit - all locomotives

t. Cab signal - all locomotives

u. Ditch lights - all locomotives

v. Horn – all locomotives

4. Qualification tests shall be performed in accordance with procedures prepared by the Contractor and accepted by the Authority and shall include, but not be limited to, the following:

   a. Qualification test (PILOT) – first three (3) locomotive

b. Road brake tests – all locomotives

c. HEP Load test – one locomotive

d. Fleet Compatibility - one locomotive

e. Wheel slip test - one locomotive

f. Fuel fill test - one locomotive

g. Noise Emission - one locomotive per class

h. Cab Sound Level - one locomotive

i. Carbody Clearance - one locomotive

5. Commissioning tests shall be performed in accordance with procedures prepared by the Contractor and accepted by the Authority and shall include, but not be limited to, the following:

a. Road brake tests (Reduced Scope) - all locomotives per contract (except Pilots)

b. Train Speed Control test – all locomotives per contract

B. Electrical Tests

1. A direct-current ground insulation test shall be performed on each locomotive after overhaul/rehabilitation as follows:

a. Disconnect all ground wires.

b. Disconnect the storage battery at its terminals

c. Megger test each nominal voltage circuit separately.

d. During this test, ground all other circuits.

2. A high-potential ground insulation test in accordance with IEEE Standards 11 and 16 shall be performed on all circuits and apparatus on each locomotive after installation.

3. After installation, the cab signal system shall be tested in accordance with the manufacturer's instructions and shall meet the requirements of 49 CFR 236, sub part E.

a. Any wire or cable that does not meet the test requirement of 49 CFR 236.522 shall be replaced.

b. Suitable documentation shall be provided as accepted by the Engineer.

4. Following the complete remanufacture of the locomotive, and prior to shipment, the following electrical tests shall be performed.

a. A complete sequence test shall be made on each locomotive, including front-rear

sequence changes, relays and switches, sanding, auxiliary motor starting circuits, wheel slip control, main propulsion and braking, main circuit breaker, calibration of safety relays, meter calibration, excitation, and any other testing required to ensure that all circuits are performing properly.

b. Ring out all wiring to ensure continuity and polarity of all new rehabilitated apparatus.

c. Make direct-current ground insulation test as noted in **Part 19.04B**.

d. A high-potential ground insulation test shall be made on all circuits and apparatus on each locomotive.

i. All wires, cables and/or apparatus which do not meet the requirements of the tests shall be removed and replaced by the Contractor.

ii. After replacement of any such defective parts, materials or equipment, the locomotive shall be subjected to re-testing.

e. Reconnect ground connection and storage battery and then test all circuits on each locomotive for proper functioning.

f. A cab signal departure test shall be made.

C. Watertightness Test

1. Each locomotive shall be water tested following the overhaul work to assure that the locomotive is water tight.

2. Watertightness is critical on short hood, cab, and roof of long hood including hatches and roof openings however the water tightness around shutters, and long hood side doors is not critical.

a. The roof, sides and ends including all hatches of each new or rehabilitated locomotive structure shall be sprayed with water.

i. The water shall be sprayed from a hand held hose with a 1/4" diameter orifice nozzle held 8 ft. 0 in. maximum from car body surfaces.

ii. The water pressure in the hose shall be approximately 40 PSI.

b. The windows and doors shall be tested for water tightness after installation.

c. All spray applications shall run for ten minutes before the leak inspection and shall run continuously during the inspection.

d. Those underfloor boxes which are required to be watertight shall be water tested after overhaul by directing a spray of water to all sides of the boxes from a hand held hose with 1/4" diameter orifice nozzle held 4 ft. 0 in. maximum from box being tested.

i. The water pressure in the hose shall be approximately 40 PSI.

ii. The water spray shall be directed at and around each box a minimum of 10 minutes before checking for leaks.

D. Engine Test

1. See Appendix D.

E. HEP Load Test

1. Head End Power Package shall perform a static test with 10 bi level coach cars to confirm sufficient power under max load.

F. Air Brake Test

1. Air brake shall be tested and adjusted until satisfactory performance is obtained to comply with 49 CFR 232.10.

a. Also, tests recommended by AAR and the air brake manufacturer shall be performed when not in conflict with FRA regulations.

2. The handbrake on each locomotive shall be tested.

a. On the first locomotive, a test to prove compliance with the Specification shall be performed using first new and then fully worn brake shoes.

b. On the other locomotives, a functional test shall be performed using new shoes.

G. Sound Emission – With equipment as described in the Specification, sound emission levels of the locomotive shall meet the following requirements:

1. External Noise Emission

a. The locomotives shall meet the requirements of 49 CFR 210, "Railroad Noise Emission Compliance Regulations" as published in the Federal Register, Volume 48, No. 248, pages 56756 through 56762, dated December 23, 1983.

2. Cab Sound Level

a. The continuous sound level in each cab during train operation shall not exceed a 12-hour, time weighted average of 82 dB (A).

i. Exposure to continuous noise (any sound with a rise time of more than 35 milliseconds to peak intensity and a duration of more than 500 milliseconds to the time when the level is 20 dB below the peak) shall not exceed 115 dB (A) at any time.

b. The 12 hour time-weighted continuous sound level shall be measured in one cab, using a precision integrated sound level meter.

i. The train shall be normally operated over a 12 hour period while a microphone is suspended in the cab at a distance of at least 12 in. from ceiling or walls.

ii. The position of microphone shall be such that it does not disturb or prevent cab operation.

iii. The height of the microphone shall correspond to the positioning of the operator's ear.

c. The locomotive chosen for testing will not be given any special treatment for the test other than the placement of the sound measuring equipment.

d. Locomotive chosen must not have any flat wheels or any significant defect which requires the operator to alter their normal method of handling the train (e.g., traction motor cutout or running at reduced power because of dirty filter or low coolant level).

e. Persons in the cab during the test will be limited to the operator, the test engineer, and a maximum of one observer.

f. Sound measurement equipment must conform to ANSI S1.4-1971 (R1976) and ANSI S1.11-1986.

g. Complete test procedures must be submitted for Engineer acceptance prior to conducting this test.

h. A report of the testing shall be submitted to the Engineer prior to final acceptance.

3. Noise Emission Badge Plates

a. Tests shall be run on one (1) locomotive. The noise emission plates as shown in Figure G76 (**Appendix F**) shall be prepared and installed in all locomotives as appropriate in a location in the cab acceptable to the Engineer.

H. Trainlines

1. MU control, communications and HEP trainlines shall be tested end to end to verify correct connection and function.

I. Communication System

1. Radio and PA systems shall be functionally tested.

J. Cab Signal

1. The Contractor shall functionally test the cab signal/ATC/ACSES system using the necessary test equipment as recommended by the equipment supplier.

2. Testing shall verify compliance with the specification and with Subpart E of 49 CFR 236, including all input/output functions related to air brake, event recorder or other locomotive systems.

3. A departure test shall also be performed and documented.

K. Layover System Test

1. A functional test of the layover system shall be performed to verify proper operation of the heating and battery charging equipment from wayside power and from the HEP.

2. This test shall also verify correct operation of the controls, indicators and system interlocks.

L. Sanding Test

a. All manual and automatic sanding functions shall be functionally tested.

M. Horn

1. The horn shall meet the requirements of 49 CFR 229.129.

N. Headlights, Ditch Lights and Marker Lights

1. The headlight and ditch lights and marker lights on each locomotive shall be aimed and adjusted to meet the requirements of 49 CFR 229.125 and 229.133 FRA regulations.

O. Weight - After completion of all other work, each locomotive shall be weighed at each truck.

1. Locomotives shall be weighed with allowance for estimated full supplies.

2. The weight tickets shall be supplied to the Authority with the Vehicle History Book.

3. The weight shall be stamped on a Weight Plate as shown in Figure G70 (**Appendix F**) which shall be installed in a location in the cab acceptable to the Engineer.

4. Two (2) trucks of each type shall be weighed.

P. Heating System Functional test

1. Controls shall be checked and adjusted for temperature distribution and proper volume of heat, to include layover heating system.

Q. Air Conditioning Function Test

1. In all locomotives, the air conditioning system shall be functionally tested.

2. The operation of the thermostatic control system shall be demonstrated by test and shall be in accordance with specified settings.

3. Controls shall be checked and adjusted for temperature distribution and proper volume of air conditioning.

R. Locomotive Sequence Tests

1. A complete sequence test shall be made on each locomotive, including front-rear sequence changes, relays and switches, sanding, auxiliary motor starting circuits, wheel slip control, main propulsion and braking, main circuit breaker, calibration of safety

relays, meter calibration, excitation, and any other testing required to insure that all circuits are performing properly.

S. Head-End Power Test

1. Functional Test – The Contractor shall perform a complete functional test of the HEP system including:

   a. Verification that all engine controls such as speed control, hot engine and low pressure shutdown, layover heat, etc., are performing properly.

   b. Verification that electrical controls such as over/under voltage and frequency, overload shutdown and remote panel functions are functioning correctly.

2. Load Test – After overhaul, with all new filters and charging engine with OEM-specified break-in lube oil, operate engine under load (dynamometer or load bank test) as follows, and record data, as indicated, including, but not limited to: voltage, current, frequency, wattage:

   a. Set up unit to run and gradually step up load until 25% load is attained.

      i. Run for one hour at 25% load and record unit data every fifteen minutes.

   b. Gradually step up load to 50%.

      i. Run for one hour at 50% load and record unit data every fifteen minutes.

   c. Gradually step up load to 75%.

      i. Run for one hour at 75% load and record unit data every fifteen minutes.

   d. Gradually step up load to 100%.

      i. Run for one hour at 100% load and record unit data every fifteen minutes.

   e. Gradually step up load to 110%.

      i. Run for fifteen minutes at 110% load and record unit data at the end of the test.

T. Body Compression or Squeeze Test

1. The locomotives as designed have passed a satisfactory compression test for which adequate records exist.

2. No body compression test will be required if the following conditions are met:

   a. The existing design is used without significant structural change.

   b. It can be satisfactorily demonstrated including calculations prepared by the Contractor that the total weight of the locomotive after all overhaul and upgrading has been completed does not exceed the original as-built weight of the locomotive

by more than 5%.

3. If the body compression test is found necessary, it shall be performed on the first locomotive as bare structure, by the Contractor, to prove compliance of the structure with this Specification.

4. The test shall be made at the Contractor's plant or other acceptable facility approved by the Authority.

5. The body, as delivered to the test facilities by the Contractor, shall be structurally complete.

    a. The body shall consist of a structure shell only, excluding such items as exterior and interior trim, windows, doors, seats, lights, insulation, interior lining, etc.

    b. Underfloor apparatus, however, may be substantially complete.

    c. Subfloor panels and floor insulation may also be installed.

    d. Other apparatus may be installed with prior approval by the Authority.

6. During the test, the body shall be supported on trucks or other acceptable devices to allow longitudinal movement.

    a. The body shell shall be loaded with sufficient dead weight to bring the total body weight up to the normal ready-to-weight.

    b. This loading shall be distributed according to the distribution of weight in the finished locomotive.

7. The pressure of the testing machine shall be applied by hydraulic power and the force measured by a means independent of those producing the force, to eliminate errors due to friction.

    a. Sufficiently recent calibration of the weighing device shall be available to assure accuracy within plus or minus 1%.

8. The test load of 800,000 lbs. shall be applied to the rear draft stops, by means of ram in the centerline of draft.

    a. No allowance shall be made for the camber of the car body.

    b. The ram shall be supported but shall remain free to move longitudinally with respect to the locomotive end.

    c. Cushioning means, such as lead sheets, shall be provided to assure uniform bearing at the draft stops.

    d. Regular draft gear carrier shall be installed and shall support the inner end of this ram.

9. Strain gauges shall be applied at points agreed upon in advance with the Authority.

a. These strain gauges shall have a means of calibrating them to suit the material used and to adjust for other factors which might affect the accuracy of the reading.

b. Strain lacquer shall be incorporated as requested by the Authority for investigation of stress concentrations.

i. SR-4 electric strain gauges, or other gauges specifically suited for the application, shall be used as required.

c. A minimum of sixty (60) strain gauges shall be used.

10. Vertical deflection shall be measured in the region of the side sill by means of a wire stretched between corner posts.

a. This wire shall be fastened at one end and kept tight at the other end by means of a weight with the wire passing over a pulley.

b. Deflections shall be measured using scales with mirrors located at the body corner posts, at bolster posts and at the center of the locomotive.

c. Deflections shall be measured to the nearest 0.01 inch and the deflections shall be considered as the average of the readings taken on both sides.

d. The deflection measured at any preliminary load application may be disregarded to eliminate the influence of whatever friction may be present.

e. Deflection between bolsters and center of locomotive shall be determined by plotting the data determined above.

11. The locomotives as designed have previously passed a satisfactory Collision Post Test for which adequate records exist.

12. At the Authority's sole discretion a further test may be required to demonstrate that the strength requirements of AAR Standard S-580 have been achieved.

U. Clearance

1. Truck clearances, lengths and location of brake air hoses and electrical jumpers, and coupler and draw-bar clearances and operation shall be checked by moving a locomotive over a curve and crossover duplicating or exceeding the most restricting track work specified as 288 ft. radius (20 degree curve) and a No. 8 Boston and Maine crossover at 12 ft. track centers.

2. Tests may be completed on suitable track on MBTA property.

V. Fueling

1. If modifications to fuel tank or fuel fill have been made, one locomotive shall be fueled using a 250 g.p.m. pump to assure fueling capabilities and proper operation of fuel cut off devices.

19.05 BRAKE TEST

A. The following brake tests shall be performed by the Contractor on three (3) locomotives:

1. A road brake test shall be performed with a train set consisting of a locomotive and a trailing load consisting of four (4) bi-level coaches or equivalent as accepted by the Engineer.

2. The Contractor shall provide instrumentation for the first three locomotives to include at a minimum, wheel temperature, brake cylinder pressures, time, distance, speed and acceleration, and test personnel to adequately evaluate the brake equipment and demonstrate stop distances and times and to verify brake performance. A reduced brake test will be performed on all other locomotives recording stop distance and deceleration.

3. The road brake test shall be performed in conjunction with the conditional acceptance track test as specified in **Part 20.05**.

4. A light locomotive shall also be tested to determine stop distance and wheel temperatures up to maximum authorized speed at ten (10) mph increments.

5. The Contractor shall also conduct concurrent wheel slip tests.

6. Reports of all tests shall be submitted to the Engineer for acceptance prior to testing of the third overhauled locomotive.

7. The blended air/dynamic brakes shall be functionally tested in accordance with Contractor's standards so that the current settings, control calibration, etc., meet the performance requirements.

   a. Actual stopping distance tests shall be incorporated into the train set track testing.

8. This test and additional tests due to failure to meet brake rates or capturing complete data for approval shall be conducted at the expense of the Contractor.

9. All instrumentation and engineering support shall be provided by the Contractor.

19.06 WHEEL SLIP SYSTEM TEST - PILOT

A. In order to provide a test of the operation of the wheel slip protection system under actual operating conditions, facilities shall be provided for a test of this system during road brake tests.

B. Instrumentation shall be maintained on this train at all times ready to record the following items simultaneously:

1. Individual axle speeds

2. Brake cylinder pressure

3. Time intervals

4. Traction motor current

C. Recording shall be by means of multiple channel recording oscillography or instrumentation

approved by the Authority.

D. Personnel shall be prepared to run this instrumentation at any time that adverse adhesion conditions may occur.

E. This test shall be continued until recordings have been obtained showing three stops and starts during which wheel slips were successfully corrected.

F. In the event that sufficiently adverse rail conditions to obtain such recordings do not occur during the test, the Contractor shall induce slips with artificial rail wetting equipment to demonstrate the performance of this system.

G. This test may be conducted in conjunction with locomotive track tests.

19.07 LOCOMOTIVE QUALIFICATION - PILOT

A. The completed locomotive with a trailing consist shall be track tested.

1. The train consist shall be the same as used in the Brake Test specified in **Part 19.05**.

B. This test shall demonstrate the satisfactory operations of all control systems, auxiliary systems, propulsion systems, and shall be conducted at a site acceptable to the Engineer.

C. This test shall be conducted to demonstrate the performance and ride quality characteristics of the locomotive.

D. The data recorded during the tests shall include, but not be limited to, the following:

1. Acceleration
2. Deceleration
3. Traction motor current
4. Traction motor voltage
5. Brake pipe pressure
6. Locomotive brake cylinder pressure
7. Dynamic brake current
8. Speed
9. Distance intervals
10. Time intervals
11. Ride quality
12. Wheel slip performance

E. This test shall be conducted at the expense of the Contractor including provision of instrumentation and engineering support.

19.08 TRAIN SPEED CONTROL TEST

A. The Contractor shall test the speed control system of each locomotive using the necessary test equipment as recommended by the equipment supplier.

1. Suitable documentation shall be provided as accepted by the Engineer.

19.09 TEST PLANS AND DATA

A. Test Data

1. All test data shall be subject to Authority review and approval, and shall become the property of the Authority upon satisfactory completion of tests.

B. Written Reports

1. Written or computer generated reports of all tests performed on the locomotives and their components shall be submitted to the Engineer for review and acceptance. No test shall be considered complete until the formal test report has been accepted by the Engineer.

a. Sample reports shall be submitted to the Engineer for approval.

2. Tests required by the Specification which are performed on all locomotives or on all components shall be included in the Vehicle History Books described in Part 24.02Error! Reference source not found..

3. Reports on all qualification tests, shall be submitted prior to final acceptance of the first locomotive.

a. Reports on qualification/type tests shall be included in the history books of the locomotives involved.

4. Written reports of all tests performed on the vehicles, systems, subsystems or components shall be submitted within thirty (30) calendar days of test performance to the Engineer for acceptance.

5. All reports shall clearly identify the equipment being tested, the date(s) of test, any conditions that may have affected results, and pass/fail status. The test record sheet shall be signed by the personnel performing and witnessing the test. All measured data shall be recorded in numeric form on the reports (not just checked off as acceptable). For each test step measured, the accepted value(s) shall be shown next to the measured value(s) recorded.

6. Copies of any charts that are taken during tests shall be part of the report (originals shall be part of the Locomotive History Book).

C. Certifications

1. The contractor shall furnish for each locomotive:

a. Four (4) copies of FRA from F-6180-49, "Monthly Locomotive Unit Inspection and Repair Report," completely filled out and notarized, for submission to the FRA, for display in the locomotive and for the files of the applicable railroad and MBTA.

b. EPA certifications for the appropriate Tier level.

c. Glazing certification of compliance with 49 CFR 223 for cab windshield and side windows.

2. If the locomotive or any related equipment or subsystems fail to satisfy the test requirements, or demonstrate noncompliance with bid performance, necessary corrective adjustment shall be made, and this locomotive shall be retested as directed by the Authority.

PART 20.00 – SHIPMENT AND ACCEPTANCE

20.01 RELEASE AND RETURN OF LOCOMOTIVES

A. The first five (5) locomotives to be overhauled shall be available to the Contractor within two (2) weeks of Notice to Proceed and shall be removed from MBTA property within 30 days of NTP Locomotives shall be removed from the property within seven (7) days of inspection.

1. The Authority's Equipment Maintenance Contractor shall prepare un-overhauled locomotives for shipment to the Contractor's plant.

2. Upon completion of overhaul, and shipment to the Authority's designated facility, the Authority's Equipment Maintenance Contractor shall prepare each locomotive for test and revenue operation including application of fuel and sand.

    a. Preparation labor charges not to exceed $1000 per unit shall be the responsibility of the Overhaul Contractor.

3. Each prepared locomotive must, after initial testing and operation, operate in revenue service for thirty (30) consecutive calendar days or 5,000 miles without incident or as approved by the Authority.

B. Commencing with the sixth (6) locomotive to be overhauled, one locomotive shall be released to the Contractor in exchange for one overhauled locomotive which has successfully completed the test described in Part T20.01A3 above.

C. The Contractor shall secure, equip, and staff a suitable facility in the within 100 miles of the Boston area for the purpose of repairing and retrofitting locomotives which the Contractor has previously overhauled at their plant.

1. The facility may be the property of, and staffed by, a third party who acts as a sub-contractor to the Contractor.

2. The facility and its operation shall not utilize equipment or staff of the Authority or its Operating Contractor.

3. The facility shall preferably be located on one of the Authority's commuter rail passenger lines so that vehicles may be readily delivered or removed by the Authority's Operating Contractor.

4. The Authority's Operating Contractor shall make a nominal charge for each vehicle movement to or from the facility.

D. Locomotives shall be shipped from the Contractor's plant without fuel, water, or sand, but with a full complement of lubricating oil as used by the Authority's Equipment Maintenance Contractor at the time of shipment.

1. During preparation of the locomotives as described in **Part 20.01A.2**, the locomotives shall be provided with full complement of fuel, water and sand at the Authority's expense.

20.02 CONSIGNMENT AND ROUTING

A. Locomotives shall be shipped dead in freight service from Contractor's plant to an MBTA designated facility within 100 miles of Boston. or other acceptable location in the MBTA service area, via the fastest scheduled service.

B. Detailed routing upon which the Contractor's price is based shall be furnished with their Proposal.

C. Final routing shall be in accordance with written instructions furnished by the Authority immediately prior to delivery of the locomotives.

D. Contractor shall be responsible for supplying accurate clearance drawings for shipping purposes as may be required by carriers, in compliance with **Part 23.03**.

20.03 CERTIFICATE OF IN-PLANT INSPECTION AND RELEASE FOR SHIPMENT

A. Prior to shipment of the locomotive(s) to the MBTA-designated facility, a final in-plant inspection of the locomotive and a review of its documentation shall be performed by the Authority's representative(s).

B. At this time the Contractor shall have compiled, for review by the Authority's representative(s), the documentation of all tests, inspections, serial numbers, weights, etc., to be entered into the individual Vehicle History Book.

C. The Contractor shall furnish to the Authority’s Engineer prior to completion of the Release for Shipment for each locomotive, two copies (2) each of the following original documents signed and dated:

1. Cab signal manufacturer's certification of compliance with all applicable FRA test requirements at the time of delivery.

2. Air reservoir manufacturer certification of any new reservoirs by type and serial number and compliance with ASME Boiler and Pressure Vessel Code.

D. Contractor shall furnish completed and signed Form FRA F6180-49A cab certificates in accordance with 49 CFR 229.25, 27, 29, and 31 in each locomotive at delivery as follows:

1. A blue periodic inspection certificate covering FRA 92-day inspection work.

2. Wording for cab cards shall be as follows:

a. Owner - XMBT - Code No. 583

E. The Contractor shall allocate up to one (1) full working day for the Authority's representatives to perform the review and inspection of each locomotive ready for shipment to assure that the locomotive totally meets the requirements of the Specification and is fully operational.

1. The Contractor shall position the locomotive over an enclosed and lighted pit and shall supply the locomotive with 130 psi station compressed air and 480 volt AC power for the duration of the inspection.

F. Upon successful completion of inspection and review by the Authority, a Certificate of In-Plant Inspection and Release for shipment will be issued by the Engineer to accompany the shipment of the locomotive(s).

1. Shipment shortages will not be permitted.

20.04 RECEIVING INSPECTION

A. Upon delivery at an Authority designated location, the Contractor's and Authority's representatives shall visually inspect the locomotive for damage, loss, vandalism, or other discrepancies incurred during shipment.

B. A Receiving Inspection Report listing all such damage, loss, vandalism, or other discrepancies shall be prepared by the Engineer and signed by the Contractor's representative(s) and the Authority's representative(s) and the delivering carrier's representative.

1. Any discrepancies noted in the Receiving Report shall be adjusted, repaired, or replaced by the Contractor.

2. Due to the regular maintenance demands on Authority facilities and on the Authority's Operating Contractor's maintenance personnel, it will be possible for said personnel to undertake only minimal adjustment, repair or replacement work on equipment prior to Final Acceptance, (see **Part 20.01C**).

3. Any defects in apparatus, material, or workmanship disclosed by inspections or tests, shall be corrected at the Contractor's expense prior to Final Acceptance.

4. All expense and costs incurred in the removal of locomotives from the designated delivery point for correction of defects shall be borne by the Contractor.

C. Receiving inspections shall be conducted and completed on Mondays through Fridays during daylight hours only, except holidays.

20.05 CONDITIONAL ACCEPTANCE INSPECTION

A. Preparation for Road Service

1. Following correction of discrepancies noted in the Receiving Report, the Contractor shall prepare the locomotive for road service.

2. In addition, the Contractor shall successfully perform a departure air brake test and cab signal departure test.

3. Supply of fuel, water, and sand will be furnished and applied by the Authority's Operating Contractor.

B. Conditional Acceptance Inspection

1. Upon completion of the preparation of each locomotive, one (1) or more static and non-revenue road tests with a train consist of four (4) to nine (9) non-ballasted passenger cars, including at least one (1) control car, will be conducted by the Authority at the expense of

the Contractor.

a. The Authority shall be responsible for determining each locomotive's readiness for normal operation in revenue service.

2. Following successful completion of the road tests, as described in **Part 20.01A.3**, a Certificate of Conditional Acceptance will be prepared and signed by the Authority's representative(s).

3. The Certificate shall note any discrepancies remaining to be corrected by the Contractor, but of such a nature that they would not preclude the further use of the locomotive in road service.

20.06 FINAL ACCEPTANCE INSPECTION (REVENUE SERVICE TEST)

A. Road Tests

1. The Authority will provide passenger car consists and train crews at its own expense for road tests of the locomotive in scheduled revenue service to further prove compliance with the various requirements of this specification.

2. Should the Contractor request, or the Authority require non-revenue road testing of the locomotive it shall be at the expense of the Contractor. The Authority will coordinate the train consist and crew, with the scheduling of such testing dependent on availability of consist and crew.

a. Due to the requirements of regular commuter rail service, non-revenue testing may need to be conducted on weekends as crews may not be available on weekdays.

3. Any deficiencies found during revenue or non-revenue road testing shall be corrected at the expense of the Contractor.

B. Acceptance Requirements

1. Locomotive Final Acceptance shall be based on the following requirements having been met:

a. Contractual and workmanship deficiencies discovered during previous inspections and tests of the locomotive have all been corrected by the Contractor in a manner judged satisfactory to the Contract requirements.

b. The Contractor has provided the Engineer with all Contract and Specification test reports showing that the tests have been successfully completed.

c. Documentation, as applicable to historic records keeping of work performed in compliance with the Contract has been delivered to the Authority.

C. Certificate of Final Acceptance

1. Following successful achievement of all Acceptance Requirements, a Certificate of Final Acceptance will be prepared and signed by the Authority's representative(s).

PART 21.00 – MATERIALS AND WORKMANSHIP

21.01 GENERAL

A. Materials and workmanship shall be in accordance with the requirements of the Specification unless otherwise approved by the Authority.

B. Inclusion of a material or method in this Part shall not necessarily indicate approval for application or use in a specific situation. Specific requirements detailed in other sections of this Specification shall take precedence over materials or methods specified in this section.

C. Material Safety Data Sheets (MSDS) shall be submitted for all materials, used in this contract. This requirement shall include lubricants but excludes non-hazardous metallic materials. Information shall be in a form compliant with ANSI Z400.1-1993

D. All workmanship shall conform to the best manufacturing practices in all respects.

E. Cleaning Agents

1. A list of recommended cleaning agents shall be provided to the Authority for all materials exposed to normal cleaning operations. This information shall also be included in the maintenance documentation for the vehicle.

F. Prohibited Materials

1. The following materials are prohibited from use on the locomotives:

a. PVC

b. Asbestos

c. Cadmium (except for battery)

d. Lead (except for battery)

e. PCBs

f. Carcinogenic materials

g. Lumber

h. Materials listed in 29 CFR Sec. 1910.19

i. Recycled Materials

2. Expendable plastic items that are recyclable shall be identified with the appropriate symbols, as defined by the Society of the Plastics Industry, permanently imbedded in the material.

G. Marking

1. All materials intended for use on these vehicles shall be marked or stored so as to be

readily identifiable and shall be adequately protected during handling and storage. Rejected material shall be clearly marked and stored in an area specifically designated for that purpose.

H. Material Handling

1. The Contractor shall exercise care in the handling of all material used in these vehicles. Examples of mishandling material include but are not limited to the following:

   a. Exposure to corrosives or other elements that may deteriorate the subject material

   b. Inappropriate storage (stacking beyond packaged limits, careless placement of material)

   c. Dragging materials across rough surfaces that may cause damage (e.g. dragging cables)

   d. Stretching materials during handling

   e. Exposure of certain materials to excessive UV light

2. Products past their expiration date shall be destroyed

3. The Authority reserves the right to direct the Contractor to change material handling methods if it is deemed necessary.

21.02 STANDARDS

A. General

1. This Section contains a partial listing of both government and industrial standards which generally apply to this Contract. All standards shall be current versions as of Notice To Proceed unless otherwise indicated. These standards shall, as a minimum, apply whether referenced or omitted in the text of any of the Sections of the Specification, drawings, or other documents. When other standards are identified within this Specification, the most rigid requirements shall apply.

2. Where other or foreign standards are proposed by the Contractor, the Contractor shall submit documentation, for the Authority's review and approval, demonstrating that the proposed standards are the equivalent of the specified standards and specifications. Proposed substitute specifications shall be submitted in both English and the language of the country of origin. The Contractor shall be responsible for assuring accuracy that the English translation is correct. The approval of the alternate standard by the Authority does not in any way relieve the Contractor of responsibility for the proper function, the adequacy of the design, or Specification compliance.

B. Government Standards

1. The following government regulations and documents shall be part of this Specification:

   a. Federal Railroad Administration (FRA) Department of Transportation (DOT)

b. FRA/DOT Code of Federal Regulations, Title 49, Transportation, Section II, Parts 200-299.

c. FRA/DOT publication, Safety Appliances and Power Brakes.

d. Americans With Disabilities Act 1990 (ADA).

e. Occupational Safety and Health Administration (OSHA)

f. The Occupational Safety and Health Act Code of Federal Regulations, Title 29 U. S. Department of Labor, Part 1910.

g. Department of Labor publication, General Industry Guide for Applying Safety and Health Standards.

h. U.S. Department of Health, Education and Welfare U.S. Public Health Services (USPHS)

i. Forest Products Laboratory Report No. 1837

j. Federal Specifications

k. Primers for Metals other than Stainless Steel, TT-P-664

l. Aluminum Paint, TT-P-38D

m. Military Specifications

n. Plymetal Panels, MIL-P-8053

o. Protective Finishes, MIL-HDBK-132

p. Finish Paint, MIL-E-15090, Class 2

C. General Industry Standards

1. The following documents form a part of this specification. Unless otherwise indicated, the issue in effect on the date of Notice to Proceed shall apply.

a. Association of American Railroads (AAR)

i. All materials, parts, and workmanship shall, as a minimum, conform to AAR requirements and the applicable sections of AAR manuals, standards, and recommended practices, including:

(a). Castings, AAR Specification M-201, Grade B

(b). Air Brake Piping, AAR Specification 2518

(c). AAR "Manual of Standards and Recommended Practices - Section A, Part III - Passenger Car Requirements (Issued 1980, rev. 1984)"

b. Aluminum Company of America (ALCOA)

i. Specification Covering Use of Aluminum in Passenger Carrying Railway Vehicles. Technical Report No. 524

c. Aluminum Association

i. Aluminum materials shall conform to the following publications:

(a). Aluminum Standards and Data

(b). Specifications for Aluminum Bridge Type Structures

(c). Engineering Data for Aluminum Structures

d. American National Standards Institute (ANSI)

i. All fasteners, splines, keysets, chains, gears, bearings, pipe fittings, pipe threads, and miscellaneous parts and equipment shall have form, fit, and function in accordance with ANSI standards and specification:

(a). Screws, Bolts and Nuts, ANSI-B18

(b). Safety Code for Safety Glass for Glazing Motor Vehicles Operating on Land Highways, ANSI-Z-26.1

e. American Society for Testing Materials (ASTM)

i. All materials and testing of materials shall be certified by tests, type tests, and/or certifications to meet the requirements of the applicable ASTM Standards and Tests, latest edition, as follows:

(a). Stainless Steel, ASTM A666

(b). High Strength Low Alloy Structural Steel, ASTM A 572, A 588, A 606, A 715, A 710

(c). Aluminum Alloy Castings, ASTM Specs. B 26, B 85, B 108

(d). Accelerated Aging-Rubber Products ASTM D 573

f. American Society of Mechanical Engineers (ASME)

i. The following procedures of the ASME shall be adhered to, to the extent specified herein:

(a). Welding and Brazing Procedures and Performance Qualification code.

(b). Boiler and Pressure Vessel code.

g. American Welding Society (AWS)

i. Practices, methods, processes, and recommendations of the AWS shall apply to the extent specified herein, and specifically:

(a). AWS Welding Handbook.

h. National Fire Protection Association (NFPA)

i. Wiring shall be in accordance with NFPA methods and materials to the extent specified herein, and specifically: NFPA Publication No. 70 (NEC).

21.03 JOINING AND FASTENING

A. Joining

1. General

a. Certain combinations of materials require particular care in joining to avoid the possibility of corrosion. The Contractor shall minimize the number of such combinations, and minimize the accumulation of water, cleaning chemicals, and chemicals present in the environment, at or near combination joints. Isolating and moisture-proofing materials, appropriate to the materials being joined, shall be used at all times where these combinations exist.

b. The Contractor shall provide a detailed plan for installation of dissimilar materials in accordance with these sections and applicable industry practice. This plan shall be submitted for approval by the Authority prior to beginning of assembly of the first vehicle.

2. Joint Fitting

a. Joints shall be properly fitted, whether exposed or concealed. When not otherwise specified in Contractor drawings or specifications, gaps between joints shall be held to a dimension not greater than 10 percent of the thinner material being joined, or 0.002 inch, whichever is greater. Gaps shall be uniform in width across 100 percent of the surface. The edges of panels shall have a smooth, finished appearance.

b. Where excessive gaps (greater than those permitted by approved drawings or standards) are found to exist at the faying surfaces of structural bolted or riveted connections, metal shims of the same material as that of the deficient part may be used, but only with the written permission of the Authority. Shims, if used, shall be permanently fastened to one of the base parts being joined. The use of epoxy or other plastic filler at such locations is expressly prohibited.

c. Metal-to-Metal Connections

i. Where metals contact each other, the contact surfaces shall be free of dirt, grease, rust, and scale. Unless specified otherwise, the contact surfaces shall be coated with a metal based primer which conforms to Society for Protective Coatings, Specification SSPC-Paint 25. Metal primer may be omitted for austenitic stainless steel to austenitic stainless steel joints.

d. Wood-to-Wood Connections

i. Where wood and wood are placed together, both abutting surfaces shall be coated with aluminum paint conforming to Federal Specification TT-P-38.

B. Fasteners

1. General

a. The Contractor and suppliers are responsible for selecting fastener types, sizes, styles, lengths, materials, grades, and finishes that shall meet the requirements of this Specification. The Contractor shall minimize the number of different sizes and styles of fasteners used. Throughout the locomotive the use of inch standard fasteners is preferred. However, ISO Metric fasteners may be used in conformance with **Part 21.03B.2.b**.

b. All fasteners used on this vehicle can be classified under one of four categories: critical; general purpose; decorative; or electrical and electronic. The criteria for classification are expressed below. All fasteners must meet the general requirements for design and material in addition to any requirements contained in the section specific to the particular category. No underfloor equipment weighing over 50 pounds shall be supported solely by fasteners.

i. Critical Fasteners – include, but are not limited to, all fasteners applied to locomotive structure, trucks, bolsters, truck-mounted brake equipment, couplers, and power collection devices. Additionally, any fastener is considered critical if failures cannot be tolerated, that is, if even a single fastener fails there is a possibility of brake failure, derailment, or accident. In the event of a dispute, the Authority shall be the final arbitrator on which fasteners are classified as critical. (see also Part 21.03B.5)

ii. Decorative Fasteners – Includes fasteners used to attach interior lining or trim and exposed to personnel view. (see also Part 21.03B.6)

iii. Electrical and Electronic Fasteners – Includes fasteners used to secure wire terminations to an electrical or electronic device.

iv. General Purpose Fasteners – Includes other fasteners not falling into one of the other three categories. (see also Part 21.03B.7)

2. Threaded Fastener Standards

a. Inch-Standard Fasteners

i. All inch-standard threaded fasteners shall conform to ASME B1.1 Standard, Unified Inch Screw Threads, (UN and UNR Thread Form) or Industrial Fasteners Institute “Inch Fastener Standards”.

b. Metric Fasteners

i. Upon approval, specific Line Replacement Units (LRUs) that are provided by a supplier or sub-supplier to the Contractor may be supplied with metric fasteners to ANSI B1.13M (ISO-metric) Standards. In these cases, all internal fasteners and threaded components of the approved unit shall have ISO-metric

threads. Internal to components there shall be no mixing of metric and inch threaded fasteners. External mounting fasteners and threaded connecting components shall have ISO-inch threads to ASME B1.1 Standards. Each unit, component, or group containing ISO-metric threads shall be indelibly identified, in an approved manner and in a conspicuous approved location, to signify that the unit contains metric threaded fasteners. All repair and maintenance manuals shall be conspicuously marked on each page where metric threaded fasteners were used within the unit. Replacement, repair, or maintenance parts supplied under this Specification shall contain all necessary replacement fasteners of the correct size and grade.

ii. Metric fasteners shall be marked as required in "Metric Fastener Standards", Industrial Fasteners Institute, latest edition.

3. Fastener Materials and Coatings

a. When making connections to heat producing apparatus, thermal expansion of the components shall be taken into consideration for selection of fastener materials. If the joined components are high expansion alloys such as copper or austenitic stainless steel, austenitic stainless steel fasteners shall be used. If the joined components are low expansion materials such as carbon steel or ferritic stainless steel, zinc plated carbon steel fasteners of minimum Grade 5 shall be used.

b. All carbon, alloy, and martensitic stainless steel fasteners shall be plated with zinc, unless specifically waived by the Authority. Cadmium plated fasteners are not permitted. Grade 8 or metric grade 10.9, or stronger, fasteners shall not be plated if the OEM finish is other than plating. The zinc plating shall conform to ASTM B633 SC2 Type II, SC3 Type II, or SC4 Type II, or ASTM B695, Class 8, Type II.

c. Alternate Fastener Coatings

i. Alternate fastener coatings are permissible if qualified by testing per ASTM B117 with no red rust or visible corrosion products after 96 hours of exposure. The Contractor shall submit qualification results for each process used at each subcontractor applying the proposed coating.

ii. In order to use an alternate coating, the vendor shall submit:

(a). Coating manufacturer's product data including required thickness,

(b). ASTM B117 test results from an accredited third party laboratory,

(c). Documentation of torque/tension characteristics, and

(d). A statement from the coating manufacturer regarding the propensity for the coating process to cause hydrogen embrittlement of the fastener during coating. Regardless of the coating's propensity for hydrogen embrittlement, each lot of high strength fasteners, including OEM plated zinc or yellow bolts (Grade 5 or Metric Grade 8.8 or higher) shall be tested for hydrogen embrittlement. Each lot of lower strength fasteners shall be tested for hydrogen embrittlement if the coating has the possibility of causing hydrogen embrittlement.

iii. If the proposed coating results in a change in the K-value for the plated fastener to outside the range of 0.13-0.15, as defined by Industrial Fasteners Institute Standard IFI-543, the vendor shall use the alternate coating on all fasteners within the particular LRU. The LRU shall contain an indelible label identifying the coating type used within the LRU and the required torque values for each size fastener used therein. Fasteners internal to a subcomponent within an LRU may use the standard coating system if they are not subject to removal during Owner's maintenance activities.

4. Joint Design

a. All screws or bolts used to secure access panels to the interior, undercar, or roof equipment shall be made captive to the panel in which they are used. All fasteners used to secure access covers, doors, or panels to equipment boxes or interior panels shall be made captive to the panel in which they are used. Where access for service is expected more often than every five (5) years, access panels shall be equipped with quarter-turn fasteners. Quarter-turn fasteners shall have a minimum shank diameter of 0.25 inch, be of adequate strength, and as manufactured by Southco, or approved equal.

b. Unless otherwise approved by the Authority, threaded fasteners shall not be threaded directly into non-metallic materials. Metal thread inserts shall be used when a threaded fastener is secured to a non-metallic material.

c. When bolts are used to secure apparatus where the bolt head is not accessible, a reusable mechanical locking device shall be used to prevent the bolt head from turning when the nut is being turned.

d. At least 1-½ screw threads shall be visible beyond all nuts. When used without elastic stop nuts, bolts shall not project more than 1-½ threads plus 0.25 inch for bolts 0.25 inch diameter or less and shall not project more than 8 threads for larger diameter bolts, unless otherwise approved. With elastic stop nuts, bolt threads shall not project more than 0.25 inch, regardless of bolt size.

e. Undercar equipment shall not be supported by bolts in tension. On a case by case basis, where redundancies exist, the Authority will consider this mounting arrangement upon evaluation of fatigue strength and consideration of safety and redundancy provisions.

f. All critical fasteners and general purpose fasteners used to secure equipment to the locomotive, including truck and brake equipment bolts and all fasteners exposed to fatigue loads, shall be torqued to a minimum preload equal to 75 percent of their proof load and "torque sealed" or "torque striped" after torquing by paint or other approved means. All other fasteners shall be torqued to a value appropriate to the application, so that they do not loosen in service.

g. Fastener installation torque for standard oiled or waxed bolts with standard or heavy hex nuts may be calculated from Industrial Fasteners Institute, Fastener Standards, equations using values for "K" of 0.18 for un-plated and 0.15 for plated threads. Locknuts shall be torqued in accordance with their manufacturer's recommendations or the Contractor may conduct tests to determine installation torque. For those nuts

or bolts requiring ”torque striping”, the Authority may require bolt torque-tension tests to verify that installed preload is equivalent to 75 percent of proof loads.

5. Critical Fasteners

   a. All critical fasteners shall have documentation identifying manufacturer and purchase specifications available for examination by the Authority at the Contractor's QA department. This documentation shall include the fastener material or grade, and finish including plating material and specifications, when applicable. Whether the buyer is a sub-contractor, supplier, or the Contractor, the Contractor shall obtain and hold this documentation for a period of not less than termination of the last locomotive's warranty period. After this period, all documentation shall be provided to the Authority

   b. All critical fasteners shall either a) be manufactured, tested, and distributed in accordance with ASME FAP-1-1990, Quality Assurance Program Requirements for Fastener Manufacturers, Distributors and Testing Laboratories, including the requirements of ASME accreditation or b) have a representative sample of each production lot of fasteners tested for conformance to purchase specifications by an independent laboratory accredited by the American Association of

   c. Laboratory Accreditation (AALA), or approved equal. A production lot is defined as one size of fastener, from one manufacturer, produced during one continuous production run. Fasteners not meeting this definition of production lot shall be treated as separate lots. Testing shall be performed using sample quantities as proposed by the Contractor and approved by the Authority. Tests conducted shall confirm that fastener material meets specified chemistry and strength requirements. The buyer shall obtain certified test results from the testing laboratory and hold the documents for a period of not less than the termination of the warranty period of the last locomotive. After this period, all documentation shall be provided to the Authority.

   d. All critical fasteners that are plated or chemically cleaned shall have certifications showing freedom from hydrogen embrittlement. Testing shall be done by the Contractor or a supplier following ASTM F519 procedures. An ASTM F606 wedge test sample may be used in place of the F519 standard samples. Test loads shall be a minimum of 80 percent of yield strength or proof load and held for a minimum of 168 hours. Any failures shall reject the entire lot.

6. Decorative Fasteners

   a. Fasteners on access panels, plates, covers, or other components accessible by passengers shall be of a single style tamperproof type approved by the Authority

   b. All decorative and appearance fasteners shall have documentation that identifies the manufacturer, base material, plating or finish if applied, and the fastener type. The Contractor or supplier shall maintain this documentation on file for the Authority to review for a period of not less than the expiration of the warranty on the last locomotive delivered. After this period, all documentation shall be provided to the Authority.

7. General Purpose Fasteners

    a. Mounting and attachment bolts shall be sized to the design strengths for Grade 2 bolts and Class A nuts, however in no case shall the fastener diameter be less than 0.375 inch. Grade 5 bolts and Class A nuts shall be used for installation of all equipment and/or structures.

    b. Fasteners used within equipment shall meet all requirements of this Section other than the requirements specifically listed for critical fasteners or decorative fasteners, and shall be sized as appropriate for the application.

    c. All general purpose fasteners shall have documentation that identifies the manufacturer, base material, plating or finish if applied, and the fastener type. The Contractor or supplier shall maintain this documentation on file for the Authority to review for a period of not less than the expiration of the warranty on the last locomotive delivered. After this period, all documentation shall be provided to the Authority.

8. Requirements for Nuts

    a. Unless otherwise required by a specific application, all nuts shall be regular height, nylon insert, self-locking stop nuts (ESNA or approved equal), conforming to Military Standard MS-21044 and Military Specification MIL-N-25027. Where nylon-insert self-locking stop nuts cannot be used, self-locking bolts and screws conforming to MIL-DTL-18240 Type L may be used. Nylon insert lock nuts, bolts, or screws shall not be used near heat sources that shall exceed the manufacturer's recommended operating temperature or 200ºF, whichever is lower.

    b. All-metal prevailing-torque type locknuts shall only be used where there is insufficient clearance to install ESNA type locknuts, or where the locknut is exposed to temperatures above 200ºF.

    c. Clip nuts shall not be used.

    d. All carbon, alloy, and martensitic stainless steel nuts shall be plated with zinc, unless specifically waived by the Authority. Grade 8, or metric grade 10.9, or stronger, nuts shall not be plated if the OEM finish is other than plating. The zinc plating shall conform to ASTM B633, SC2 Type II, SC3 Type II, or SC4 Type II, or ASTM B695, Class 8, Type II.

    e. Alternate coatings may be applied to nuts per the requirements of **Part 21.03B.3**.

9. Washers and Retention Devices

    a. Washers, of a grade and strength compatible with the fastener, shall be used under the heads of all bolts and under all nuts. Washers shall conform to ANSI B18.22.1 or ANSI B18.22M, latest revision, as is appropriate for the application. Where high strength fasteners are applied, washers shall be hardened and comply with IFI Fastener Standards.

    b. Lock washers shall not be used for fatigue applications where the fastener must be torqued and marked per **Part 21.03B.7**. The use of lock washers is discouraged

throughout the vehicle and all systems. Other types of washers, including Belleville washers, may be used for special applications with the Authority's approval. Lock washers, when applied, shall conform to IFI Fastener Standards.

C. Bonding

1. The joining of elastomeric pieces shall be conducted by the hot vulcanization process. Adhesive bonding of elastomers shall not be allowed.

2. All adhesive applications shall be approved by the manufacturer of the adhesive system and suitable for the materials being joined and the environmental exposure to be expected. Where adhesives are in contact with painted surfaces, suitable bond strength to both the paint and substrate shall be verified by test. The Contractor shall submit manufacturer's data for all proposed adhesive applications prior to first use of the adhesive system.

D. Rivets and Lock Pins

1. Rivets and lock pins exposed to passengers or crew shall be austenitic stainless steel or aluminum, as appropriate to the materials being joined. Structural steel rivets shall conform to ASTM A 502 or American National Standard B 18.1.2 standards. Rivets may be hand driven when hot and shall completely fill the rivet holes. Rivets driven cold shall be mechanically driven. Exposed heads shall be concentric with the shank and free from rings, fins, pits, and burrs.

2. Swage-locking (Huckbolt type) fasteners shall conform to Military Specification MIL-P-23469. All rough surfaces of the collar end of these fasteners shall be machined or ground smooth where accessible to passengers, crew, or maintenance personnel performing routine maintenance functions. the Authority shall be the final arbiter in determining whether an application is hazardous to maintenance personnel.

E. Rivet and Bolt Holes

1. Rivet and bolt holes shall be accurately located and aligned, and, when necessary during assembly, holes shall be reamed round to specified size in position. Bolt hole clearances shall not exceed the Industrial Fasteners Institute's requirements. All removed and replaced rivets shall have the holes reamed to the size required such that the next larger rivet may be driven securely. Slotted holes may be used only where necessary and approved. Heavy flat washers shall be used at all slotted holes.

21.04 WELDING AND BRAZING

A. General

1. The Contractor shall be responsible for the quality of its welding and brazing as well as that of its suppliers and subcontractors. Cleaning prior to welding shall be in accordance with applicable parts of Section 2, MIL-HDBK-132, "Cleaning Materials and Processes."

B. Structural

1. All structural welding practices shall be according to requirements of the AWS D1.1, "Structural Welding Code-Steel;" AWS D1.2, "Structural Welding Code - Aluminum;"

AWS D1.3, "Structural Welding Code - Sheet Steel;" AWS D1.6, "Structural Welding Code- Stainless Steel;" AWS D15.1 "Railroad Welding Code", and the AWS Welding Handbook. Requirements for dynamically loaded structures shall be applied. Cast steel welding shall be according to ASTM A488/A488M, "Steel Castings, Welding, Qualification of Procedures and Personnel." Resistance welding shall be in accordance with AMS-W-6858B. AWS D1.1 shall apply to steel of 0.125 inch and greater thickness. AWS D1.3 shall apply to steel less than 0.125 inch thickness. Canadian Welding Bureau (CWB) Standard W59, "Welded Steel Construction," may be used in lieu of AWS D1.1 and CWB Standard W59.2, "Welded Aluminum Construction," may be used in lieu of AWS D1.2. In the case of the use of CWB standards, AWS standards shall be used for all materials and thicknesses where CWB standards do not apply.

2. Structural welding of ferritic and austenitic stainless steel shall primarily be governed by AWS D1.6. ASME Section IX and ASME Section VIII, Part UHA shall apply where appropriate. 201L (UNS 20103) and 301LN (UNS 30153) stainless steels shall be treated as P-No. 8, Group-No. 3, category for reference to ASME requirements. Ferrite number for welds made with austenitic stainless filler materials shall be between WRC4 and WRC10, or as proposed by the Contractor and approved by the Authority. Weld heat-affected zones (HAZ) and weld metal shall be limited to maximum allowable stress values in ASME Section VIII, Table UHA-23, for UNS S20100 stainless steel and Table UW-12 rating of welds. Fatigue allowable stresses shall not exceed the lesser of fatigue limits in AWS D1.1, Section 2.20.6, or 50 percent of the joint strength level calculated from ASME maximum allowable stress values. Higher values shall only be used if qualified by Contractor tests.

3. Regardless of the governing codes, all Welding Procedure Specifications (WPS) shall be fully qualified by test by the Contractor. Qualification shall be documented by Procedure Qualification Records (PQR). WPS and PQR shall be prepared by the Contractor and reviewed and accepted by the Authority and a Certified Welding Inspector. The use of AWS-B2.1 guidelines for qualification shall not be permitted and shall not be included or referenced in WPS and PQR. The use of any WPS purchased from an outside agency shall not be permitted without separate qualification by the Contractor.

C. Welder Qualification

1. Welders shall make only those welds for which they have been qualified according to the requirements of the AWS, ASME Section IX, ASTM A488/A488M, or other approved qualifying procedures. AWS B2.1 "Standard for Welding Procedure and Performance Qualification", may not be used for welder qualification. Records of welder qualification tests shall be made available for review.

D. Inspection of Welds

1. The Contractor shall visually inspect all structural welds in accordance with AWS D1.1 requirements.

2. In addition to the visual inspection specified for all welds, nondestructive surface inspection (dye penetrant or magnetic particle methods, as appropriate) shall also be used to inspect all first-production welds. The Contractor shall specify a sample nondestructive inspection rate for all subsequent welds.

3. If ring welds are used, on the first structure all ring welds shall be nondestructively inspected by magnetic particle or dye penetrant methods. The Contractor shall submit a random sampling plan for additional metallographic examinations of ring welds for approval. The minimum acceptable sampling plan shall require inspection of one (1) ring weld sample for every 300 production ring welds. A record of all NDT inspections shall be included in the Car History Book.

4. On the first structure, all full penetration welds shall be nondestructively, volumetrically inspected (ultrasonic or radiographic methods) according to AWS D1.1 requirements. The Contractor shall specify a random sampling plan for volumetric inspection of subsequent, full-penetration welds for approval. The minimum acceptable inspection plan shall require inspection of one (1) portion of a full penetration weld for every 200 production welds. The proposed test welds shall be selected from among welds that are most critically loaded as determined by calculation or load test. With approval, destructive sectioning and metallurgical examination may be substituted for some or all of the required volumetric inspection requirements for production welds.

E. Post-Weld Cleaning Requirements

1. All welds visible to passengers or on sliding contact surfaces of truck frames and bolsters shall be completely cleaned of spatter.

F. Contractor Documentation

1. All welding procedures and documents, including Welding Procedure Specifications, Procedure Qualification Records, and Resistance Spot Welding Schedules, shall be submitted for approval before application. Specifications for purchase of welding electrodes, welding wires, and cover gases shall be submitted for approval before their application.

G. Dissimilar Metal Welding

1. Procedures and qualification records for structural welding of stainless steel to LAHT shall be submitted for approval. As part of the qualification of all dissimilar metal welds, sample welds shall be sectioned and examined metallographically to determine HAZ hardness. The HAZ hardness shall not exceed 400 HV (Vickers Hardness).

2. Austenitic stainless steel electrodes or wire shall be used to join carbon or LAHT steels to stainless steels.

3. Galvanized steel shall not be welded to stainless steel.

H. Resistance Welding

1. Resistance welding of stainless or carbon steels shall be according to AMS-W-6858B, Class B for structural applications and Class C for non-structural applications. All resistance welding procedures shall be qualified per AMS-W-6858B; procedures and qualification records shall be submitted for review and approval. Contractor-proposed deviations from AMS-W-6858B, including, but not limited to, weld nugget diameter, tension shear strength, and minimum spacing, shall be submitted and approved before application in production.

2. Design strengths higher than standard certification and production strength requirements shall be qualified according to AMS-W-6858B, Figure 11b, for one (1) thickness combination. This shall require a test lot size of 180 spot welds. Additional thickness combinations with the same increased strength ratio may be qualified by twenty-five (25) spot weld shear tests plus three (3) macro-sections. Twenty (20) of the twenty-five (25) shear test specimens may be recorded from production witness tests taken from twenty (20) consecutive production days (not calendar days). The Contractor shall submit records of the settings, ultimate shear strength, weld diameter, and weld penetration for approval.

3. Surface indentation shall not exceed 20 percent of material thickness or 0.01 inch, whichever is greater. However, for exterior resistance-welded areas exposed to passenger view, indentation shall not exceed 10 percent of t or 0.005 inch, whichever is greater. For exposed welds, the Contractor shall vary welding parameters and conditions within their acceptable ranges to minimize indentations. Surface burn and discoloration shall be removed by chemical cleaning, or an approved equal method, and sanding or polishing to match the surrounding surface.

4. Production witness welds shall be made and tested once each day and, in addition, whenever otherwise necessary such as by change in any of the following:

    a. Operator

    b. Material, material thickness, or combination of thicknesses

    c. Electrodes

    d. Settings

I. Resistance Spot weld and Intermittent Weld Spacing

1. Spacing of resistance and spot welds shall be according to approved structural drawings. Spacing of welds contributing to carbody stiffness shall not exceed 2 inches plus twice the weld nugget diameter for any structural application, including carbody side sheets, roof sheets, and corrugation. For any application to corrugations, if the pitch of the corrugation nodes does not allow the above weld spacing, there shall be 2 spot welds between each node.

2. For intermittent fusion-welds contributing to carbody stiffness, spacing pitch shall not exceed 5 inches for 2 inch (minimum) weld lengths (40 percent minimum of length welded).

3. For structural members not contributing to carbody stiffness, the intermittent welds joining structural members contributing to the stiffness of other members must conform to the spacing criteria above. All other intermittent welds shall be designed and qualified in accordance with the appropriate welding code requirements.

J. Toughness of Welded Assemblies

1. The Contractor shall prove that all welded steel structures are above the ductile-brittle transition temperature for the specified environmental exposure. Specifically, the weld heat-affected zone (HAZ) and base metal shall resist service impact loads at the lowest

specified operating temperature without brittle failure. In the absence of prior operating history, and if the Contractor's approved design does not require greater toughness, the minimum impact value for Charpy V-notch specimens shall be 15 foot-pounds of absorbed energy at -20°F.

2. the Authority shall have the right to require impact tests to verify the specified toughness. If tests are required, verification of HAZ toughness shall be done on a test sample welded according to PQR parameters. Base metal toughness shall be certified on a heat basis by the steel manufacturer or steel supplier; if these data are not available, the Contractor shall perform tests on each heat of as-received base metal.

K. Torch Brazing

1. All brazing, defined as heating above 840°F without base metal melting, shall follow the recommendations of the AWS Welding Handbook, Volume 2, latest issue. Procedures and personnel who perform brazing work shall be qualified in accordance with AWS B2.2, "Standard for Brazing Procedure and Performance Qualification". Records of brazing procedure and performance qualification shall be submitted for approval.

L. Torch Soldering

1. All structural (not electrical) soldering, defined as heating below 840°F, shall follow the recommendations of the AWS Welding Handbook, Volume 2, latest issue. Procedures and personnel who perform torch soldering shall be qualified through the preparation and testing of samples of production torch soldering. Test samples shall be prepared and submitted for approval before production torch soldering.

21.05 STAINLESS STEEL

A. General

1. Permitted uses of structural stainless steels are specified throughout this Specification. Ferritic stainless steels shall be painted where exposed to passengers or the weather. Austenitic stainless steels may be unpainted. Unpainted stainless steels exposed to passengers shall be a single grade of austenitic stainless steel in which both the color and surface finish of abutting pieces shall match, except where the design specifically calls for contrasting appearance.

B. Austenitic Stainless Steel

1. Structural austenitic stainless steel components assembled by fusion or resistance welding shall be of AISI type 201L (UNS S20103), 301L (UNS S30103), 301LN (S30153) or JIS SUS301L (with Nitrogen) and shall conform to the requirements of ASTM A666 except that the carbon content shall not exceed 0.03 percent and type 301LN and SUS301L (with Nitrogen) shall not exceed 0.25 percent nitrogen. Other stainless steels conforming to ASTM A666 are acceptable for non-welded applications.

2. Stainless steel used in structural applications covered by this Specification shall also conform to APTA SS-C&S-004-98 Standard for Austenitic Stainless Steel for Railroad Passenger Equipment.

3. General requirements for delivery of stainless steel shall be as required by the

Certification Provisions of ASTM A666. Stainless steel to be used in structural applications shall be tested for susceptibility to intergranular corrosion in accordance with ASTM A262, latest revision. Practice A of ASTM A262 can be used to accept material only; Practice E is required for final determination of acceptance or rejection of material that is not acceptable by Practice A.

C. Ferritic Stainless Steel

1. When specified, ferritic stainless steel conforming to ASTM A176 may be used for sheeting up to 0.2 inch thickness. Ferritic stainless steel sheet shall have a ductile-to-brittle transition temperature (DBTT) or nil-ductility temperature (NDT) below 0°F. Weld heat-affected-zones shall also have a DBTT or NDT below 0°F. Ferritic stainless steel sheet shall have a balanced composition (low carbon and/or suitable titanium content) that shall, for all conditions of fabrication and assembly into the locomotive body, inhibit formation of martensite and limit chromium depletion in weld-heat-affected zones so that material shall meet ASTM A763 requirements for resistance to intergranular corrosion.

2. General requirements for delivery of ferritic stainless steel shall be as required by ASTM A480.

3. Where ferritic stainless steels are welded to other structural steels, the less-noble steel shall be painted with weld-through primer.

D. Testing

1. The Contractor shall prepare (or have prepared), submit, and receive approval of a test and inspection plan for acceptance of all stainless steel to be used in welded applications prior to purchasing any such material. The tests and inspections shall verify that the stainless steel conforms to specified requirements. For austenitic stainless steels, the test and inspection plan shall include frequency of submittal of certifications in accordance with Certification Provision of ASTM A666 and frequency of submittal of checks for susceptibility to intergranular corrosion in accordance with ASTM A262. For ferritic stainless steels, the test and inspection plan shall include frequency of submittal of checks for susceptibility to intergranular corrosion in accordance with ASTM A763.

E. Flatness Tolerance

1. Coil stock shall meet standard mill flatness tolerances, unless otherwise specified. Sheet stock shall be of stretcher-leveled quality.

F. Finishing Methods

1. Unless otherwise specified, all smooth sheets exposed to passengers shall be given a medium-grit finish on the exposed side using a belt or oscillating sander. Grain shall be in a direction to suit the decorative treatment in the interior of the locomotive.

21.06 LOW-ALLOY HIGH-TENSILE STEEL

A. General

1. Low-alloy high-tensile (LAHT) steel structural shapes, plates, and bars shall, as a

minimum, conform to the requirements of ASTM A588, where available. Plate steel may alternatively conform to ASTM A710; Grade A, Class 1, 2 or 3. Where not available in A588, hot rolled or formed structural shapes conforming to ASTM A36 may be used for limited applications including equipment supports and jack pads. General requirements for delivery of LAHT shapes, plates, and bars shall be as required by ASTM A6.

2. Cold and hot rolled LAHT sheet and strip shall, as a minimum, conform to the requirements of ASTM A606, Type 4. General requirements for delivery of these products shall be as required by ASTM A568.

3. Other low-alloy, high-tensile steels which meet or exceed the above minimum requirements may be used, provided their detailed specifications are submitted and approved as equivalent, or better material, for the proposed applications. All LAHT steels shall be applied according to their specification properties.

4. Welded LAHT steel shall develop 15 foot-pounds Charpy V Notch impact strength in the CGHAZ (Coarse grain heat affected zone) 0.03937 inches from the fusion area at -20°F.

5. Material used for repairs shall conform in composition and dimension to the original material being repaired or replaced.

B. Testing

1. The Contractor shall prepare (or have prepared), submit, and receive approval of a test and inspection plan for acceptance of all structural steels in accordance with the requirements of this Section before purchasing any such material. The test and inspection plan shall include provisions for submission of reports and certification to the Authority for each shipment in accordance with the applicable requirements of the purchase specification and specified CGHAZ impact tests.

21.07 STEEL CASTINGS

A. General

1. The Contractor shall be responsible for selecting casting grade, composition, strength, and finishing. However, steel castings, used in the carbody structure and truck assemblies shall meet AAR Specification M-201 latest revision, Grade “B”, plus two percent nickel, minimum. These castings shall be heat treated to develop a minimum tensile strength of 75,000 psi, minimum yield strength of 48,000 psi, elongation of not less than 25 percent in 2-inches, and reduction of area of not less than 50 percent. Also, steel castings used for coupler, drawbars, and anchors shall meet AAR Specification M-201, latest revision, Grade “C” or “E”, quenched and tempered.

2. Where cast steel of superior properties is required for a specific application, the Contractor may propose such castings for review and approval of the Authority.

3. Stainless steel composition and processing must be selected such that the castings shall be able to meet or exceed the strength required by the specified application, as determined by the Authority. Stainless steel castings shall be made in accordance with appropriate ASTM standard(s), depending on the type of stainless steel used. Other standards may be used upon the Authority approval.

B. Design Qualification of Structural Castings

1. One steel casting, selected by the Authority from the first lot of production steel castings, shall be subjected to a qualification test of the casting design by the Contractor. A statistical sample of stainless steel castings, as agreed upon by the Authority and the Contractor, from the first lot of production stainless steel castings, shall be subjected to a qualification test of the casting design by the Contractor. Qualification tests shall include radiographic examination for material soundness using reference radiographs to ASTM E 446 and any mechanical testing.

2. Acceptance levels for the design qualification radiographic examinations shall be selected by the Contractor as appropriate for the service intended, subject to the approval by the Authority before any castings are produced. Radiographs shall meet the requirements of ANSI/ASTM E 94 and E 142 for steel castings, and ASTM E 1742 for stainless steel castings, and the quality level in the area of inspection shall be at least two percent (2-2T).

3. A qualification test report shall be prepared and submitted to the Authority for approval. The production of any castings before receipt of the Authority's approval of this report shall be at the Contractor's risk. All radiographs from the qualification test shall be made available to the Authority for review. If the casting selected for qualification fails to qualify, a plan of action, including details of how failed material shall be handled, shall be included in the qualification test report. Once a design is qualified and accepted by the Authority, no changes shall be made in the casting pattern, technique, heat treatment, or material composition without requalification in accordance with the requirements of this Section.

C. Quality of Structural Castings

1. All structural castings supplied shall be equal to or better than the design qualification castings in all respects. The casting supplier or Contractor shall test, inspect, and accept castings in accordance with procedures described in AAR Specification M-201 for steel castings. For stainless steel castings, the procedures shall be proposed by the Contractor and approved by the Authority. In addition, the inspections below, as applicable, shall be performed and a written report of the results of the tests and inspections shall be furnished for each lot of castings produced.

a. Magnetic Particle Inspection

i. Magnetic particle inspections of all surfaces of each casting shall be conducted, according to ASTM E 709, by personnel certified to MIL-STD-410. With respect to structural castings, including coupler castings, the maximum permissible magnetic particle indications shall be not more than ¼-inch in the direction transverse to the usual direction of loading, and no more than ¾-inch in the direction parallel to the usual direction of loading.

ii. For martensitic and ferritic stainless steel castings, acceptance criteria shall be in accordance with ASTM A 903.

b. Radiographic Inspection

i. Radiographic inspection of steel castings shall be conducted according to the requirements of ASTM Standards E 94 and E 142, using reference radiographs to ASTM E 446. Radiographic inspection of stainless steel shall be conducted according to the requirements of ASTM Standards E 94, E 1742 and E 1030. A sampling frequency shall be proposed by the Contractor and submitted for approval by the Authority.

ii. Structural castings shall not exceed severity level 3 of ASTM E 446 in all critical areas of such castings and shall not exceed level 5 in all other areas of the castings. During demonstration that the stated severity level requirements of ASTM E 446 have been met, successively produced castings shall be re-inspected by radiography in the defective areas shown in the prior radiographic inspection. After such severity levels have been proved, the sampling frequency for structural castings shall be one casting out of each 10 produced. If no castings are rejected by radiographic inspection, this frequency may be extended to one casting in 25.

c. Liquid Penetrant Inspection

i. For non-magnetic stainless steel castings, liquid penetrant inspections of all surfaces of each casting shall be conducted according to ASTM E 165, by personnel certified to MIL-STD-410. Acceptance criteria shall be established in accordance with ASTM A903.

D. Repair Welding and Cast-Weld Design

1. Repair welding of steel castings is permitted, provided the casting supplier performs all repair welds according to the structural welding requirements of this Specification. Castings requiring repair or modification by welding after completion of heat treatment may be stress relieved locally by using electrically-controlled heating to a temperature not greater than 1150ºF and slow cooling. Manual torch stress relief shall not be permitted except for cosmetic welds and only then after the procedures have been submitted for review and approval. For cast-weld designs, the entire length of all assembly welds on any welded assembly of several separate castings selected for design qualification shall be radiographically inspected to ANSI/ASTM E 94 and E 142, using reference radiographs from the International Institute of Welding's "Collection of Reference Radiographs of Welds," quality level Green. Portions of assembly welds stressed in tension by service loads shall meet quality level Blue.

2. No repair welding of stainless steel castings is permitted without express written approval of the Authority.

E. Disposal of Non-Conforming Castings

1. If castings are found to be non-conforming to requirements determined by the design qualification castings, the material shall be repaired, retested, and reinspected or destroyed and replaced at the Contractor's expense.

21.08 ALUMINUM

A. General

1. Aluminum alloy mill products shall be identified by Unified Numbering System designations and shall conform to The Aluminum Association specifications contained in the Association's publication "Aluminum Standards and Data". Aluminum alloy castings shall conform to ASTM B26, B85, or B108 for, respectively, sand, die, or permanent mold castings. Aluminum alloy forgings shall conform to ASTM B247. Copies of all test reports for sheet, extrusion, and forgings used in the locomotive structure shall be submitted to the Authority.

B. Fabrication and Fastening

1. The forming of aluminum parts; joining of parts by bolting, riveting, and welding; and the protection of contact surfaces shall, as a minimum, conform to the requirements of the Aluminum Company of America's Technical Report No. 524, 'Specification Covering Use of Aluminum in Passenger Carrying Railway Vehicles", except as otherwise specified herein.

2. Fabrication techniques shall be such that the strength and corrosion resistance of the aluminum shall not be impaired nor the surface finish permanently marred or discolored during construction.

C. Protection of Contact Surfaces

1. The specific measures to be taken by the Contractor to prevent the risk of direct metal-to-metal contact and resultant possible electrolytic corrosion shall be approved and shall depend upon the determination of the most suitable method which can be adapted to the design involved. The following instructions shall be the minimum protection.

a. Aluminum alloy surfaces shall not be secured to or make direct contact with the surfaces of copper, copper bearing aluminum alloy, brass, bronze, silver, nickel, nickel alloys, nickel plated parts, lead, tin, or wood.

b. The contact surfaces of aluminum alloy with aluminum alloy shall be painted with zinc chromate primer or approved equal before securing.

c. The surfaces of aluminum alloy parts secured to steel parts, where exposed to weathering or harsh environments, shall be protected with a one-part polysulphide sealant, zinc chromate paste, mica insulation joint material, or an approved equivalent material which completely covers the faying surfaces. The insulating material shall be non-hygroscopic and, if fibrous, shall be impregnated with bitumen or an approved, non-corrosive, water and moisture-repellant substance. After driving, fasteners shall be primed and painted with red oxide or aluminum paint.

d. Stainless steel and carbon steel fasteners plated with zinc shall be coated with zinc chromate paste or approved equal before installation. Where possible, only the head and the shank of the bolt shall be in contact with the aluminum part when secured in place. Suitable bushings may be used in place of the zinc-chromate paste.

D. Interior Trim

1. Where unpainted aluminum is exposed to contact by personnel, it shall have a clear (natural)

anodic finish. The finish process shall be the Aluminum Company of America's "Alumilite 204" with a minimum coating thickness of 0.0004 inch and a minimum coating weight of 21 milligrams per square inch, or approved equal process.

21.09 ELASTOMERS

A. General

1. Elastomers shall be compounded and cured to perform as intended in the environment specified in Part 1.06. Elastomers shall have high resistance to ultraviolet and other solar radiation, weather and to all the Authority car-washing and cleaning fluids. All elastomeric parts shall be resistant to ozone, oxidation, heat, oil, grease and acid, and shall have the longest possible life, consistent with the other characteristics specified.

2. The following elastomeric parts shall be of an applicable compound unless otherwise specified or approved:

   a. Glazing Rubber,

   b. Door Seals,

   c. Door Nosing,

   d. Other parts exposed to the outdoor ambient environment, except where otherwise specified.

   e. The following elastomeric parts shall be of natural rubber, (synthetic rubber compounds are not permitted) unless otherwise specified or approved:

   f. All resilient mounts,

   g. Elastomeric truck components.

3. Elastomers used within pneumatic or hydraulic equipment shall be as necessary to meet the performance requirements of this specification for the pneumatic or hydraulic device.

4. All elastomeric parts are to be marked with the date of manufacture and shall not have aged more than 12 months when assembled into the locomotive.

B. Life Expectancy

1. For all parts made by vulcanizing an elastomer to metal, any premature failure (less than six years) between metal and the elastomer or in the elastomer, occurring when the parts are used in normal service and according to the provisions of this Specification, shall be considered as having been caused by defect of materials or workmanship.

C. Metal Parts

1. Metal parts to which elastomeric material is vulcanized shall be made of SAE 1020 or 1045 hot-rolled steel.

D. Truck Parts

1. Truck bumpers, snubbers, and the exterior surfaces of air springs shall be made of natural rubber or approved equal. They shall be compounded to be resistant to abrasion, oil, grease, and acid.

E. Seals

1. Glazing strips shall be of neoprene conforming to ASTM C542, or approved equal material.

2. All door mating edges, door and window seals, and glazing strips shall be of neoprene material. The durometer hardness measured with a Shore Type "A" durometer at a temperature between 70°F to 90°F shall be 70 ±5 except for the side door mating edges where it shall be 80 ± 5.

F. Bonding

1. The joining of elastomeric pieces shall be conducted by the hot vulcanization process. Bonding of elastomers by other processes shall not be allowed unless the Contractor submits the application, bonding procedure and bonding agent technical data for approval prior to the purchase of any materials.

G. Tests

1. All tests shall be conducted according to the latest revisions of the specified ASTM test procedures, unless otherwise specified, and the results of the testing shall be submitted to the Authority.

2. The test specimens shall be cut out from the extruded material, and at least one tensile strength and elongation test and one accelerated aging test shall be made on the material used for each order. If the compound or cure, or both, are changed during the production of material for one order, at least one test of each type shall be made for each different batch.

3. When testing the 6 inch by 0.50 inch ASTM "dumb bell" type test specimen (or smaller size if the size of the part necessitates) by the methods specified in ASTM D3182, D3183, D3190, and D412, the tensile strength shall not be less than 1,500 psi and elongation shall be a minimum 350 percent. The tensile strength of the elastomer shall not be reduced more than 25 percent when subjected to accelerated aging by the methods specified in ASTM D573, for a period of 96 hours in an air oven at 158°F.

4. The ozone resistance of the elastomer shall be tested in accordance with ASTM D1149 using an ozone concentration of 100 pphm, an exposure time of 100 hours at 100°F, and a specimen elongation of 20 percent. The elastomer shall not exhibit any cracks during the test period.

5. All elastomers shall be also tested according to the Flammability, Smoke Emission, and Toxicity section of this Specification.

21.10 GLAZING MATERIALS

A. Safety Glass

1. Safety glass shall meet the requirements under Item 1, Table 1 of ANSI Z26.1, "American National Standard for Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways - Safety Code" and FRA 49 CFR 223 Type I or II test as appropriate for the application.

2. Type

    a. All safety glass shall be of the laminated sheet type.

3. Flatness

    a. When an individual light of glass is laid on a truly flat surface, such as a surface plate, the glass shall not indicate a bow of more than 0.030 inch per linear foot.

4. Dimensional Tolerance

    a. The overall dimensions of individual lights as supplied shall be held within 0.060 inch of the dimensions ordered.

5. Overlap Tolerance

    a. The overlap of one laminate of the light with respect to the other at an edge shall not exceed 1/32 inch. Corners and burrs shall be ground smooth and all edges shall be treated in accordance with ANSI Z26.1, Section 6.

6. Color

    a. The color of the glass shall be as specified. When new, there shall be no more than ± 4% variation in the color of individual lights of laminated sheet glass when examined over a white background.

7. Haze

    a. All the laminates of the safety glass shall be so nearly free from haze that the glass shall have approximately the same clarity as a light of the same nominal thickness of plate glass when viewed against a north light.

8. Specks and Scratches

    a. Occasional specks of foreign material and scratches are permissible, provided such specks do not exceed 0.020 inch in greatest dimension and scratches do not exceed a total of 3 inches in length and neither are within the central three-quarters area of the light.

9. Bond Separation

    a. The bond between two sheets of glass and the membrane shall be of such quality that when the glass is broken by twisting or by direct impact, there shall be no separation between the glass sheets. Lights that contain un-bonded areas shall not be used.

10. Marking

    a. Each light shall be marked for identification by the supplier in legible letters 0.1 inch high in the lower right hand corner as viewed from the inside of the vehicle. This identification shall be no closer than 3/4 inch to the edge. The identification shall give the product name, the manufacturer, the serial number, and FRA Type designation. Markings shall be legible and permanent for this application and shall be applied in such a manner so as not to reduce the integrity of the material. Markings are to be in accordance with ANSI standard Z26.1 and 49 CFR Part 223. The light shall be installed so that the identification can be read from the inside.

11. Quality Assurance

    a. The Contractor shall be responsible for the performance of all inspection and test requirements. Except as otherwise specified, the Contractor may utilize the facilities of its supplier or any approved commercial laboratory.

12. Shipping

    a. The material shall be carefully prepared for shipping and shall be properly protected to prevent damage. If a pressure sensitive masking is used, it shall be easily stripped from the material and not leave a gummy or sticky residue.

13. Documentation

    a. The Contractor shall certify that the shipped material complies with the requirements in this Specification.

B. Plastic Glazing

1. General

    a. Plastic glazing shall meet the requirements under Item 4, Table 1, of the latest revision of ANSI Z26.1, "American National Standard for Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways – Safety Code." The material shall be selected from General Electric Company "Margard," Atohaas "Tuffak CM-2," or approved equal, meeting 49 CFR 223 and 238.

2. Applicable Documents

    a. The latest issue of the following documents, in addition to those specified in this Section, shall form a part of the Specification:

        i. ASTM D 673 – Mar Resistance Test.

        ii. ANSI Z26.1 – Item 4, Table 1, "American National Standard for Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways – Safety Code."

        iii. ASTM G 23 – Recommended Practice for Operating Light – and Water – Exposure Apparatus (Carbon Arc Type) for Exposure of Nonmetallic

Materials.

iv. ASTM D 1499 – Recommended Practice for Operating Light – and Water – Exposure Apparatus (Carbon Arc Type) for Exposure of Plastics.

v. ASTM D 1003 – Recommended Practice for Determining Haze Factor.

vi. ASTM E 162 – Radiant Panel Test For Determining Flame Propagation Index (Is).

vii. 49 CFR Part 223 – Impact Requirements.

viii. ASTM E 662 – Test to Determine Smoke Emission Values (Ds).

3. Strength

a. Samples shall be prepared and tested according to 49 CFR 223 and 238 and Test Number 10, Article 5.10, of ANSI Standard Z26.1. Samples shall not shatter or break when subjected to the falling dart impact requirements of Test Number 10. The dart tip shall be no more than 0.50-inch radius. Denting or marring of the surface of the tested piece in this test is permissible.

4. Light Transmission

a. Visible light transmission through clear plastic glazing shall not be less than 85% in 0.125-inch thickness, 82% in 0.250-inch thickness, 80% in 0.375-inch thickness, and 78% in 0.5-inch thickness.

b. Visible light transmission through tinted plastic glazing shall be as specified.

5. Weathering Test

a. The materials shall pass the long arc Xenon lamp-weathering test Number 16 of ANSI Standard Z26.1.

6. Color

a. The color of the plastic glazing shall be as specified. The material shall be integrally colored and shall have UV stabilizer additives to inhibit fading and loss of properties due to extended exposure to direct sunlight. When new, there shall be no more than 4% variation in the color between lights of plastic material of a specified color and thickness, when examined over a white background, and measured by the appropriate light transmission or color meter inspection and test instruments.

7. Abrasion Resistance

a. Plastic glazing materials shall be silicone-coated on both sides to increase resistance to abrasion. The coated plastic shall meet the following specifications:

i. Property

ii. Test Method

iii. Requirements

iv. Abrasion Resistance

v. ANSI Z26.1 Test 17

vi. The change in percent haze after 100 cycles shall be less than six

b. The glazing material supplier is required to perform the following test prior to qualification: The plastic glazing material after 300 hours of weatherometer testing shall pass abrasion resistance ANSI Z26.1 Section 5.17. The foregoing test is to be performed for initial product certification.

8. Chemical Resistance

a. Samples shall be prepared and tested according to Test 19, Article 5.19, of ANSI Z26.1. The exposed fabricated edges of the test samples may be coated with the same material as the face surfaces by the manufacturer. In addition to those chemicals specified in this test, the test shall also include, but not be limited to, such cleaning solutions as used by the Authority for cleaning locomotives. The exposure time of the test shall be increased to one-hour intimate contact with the test chemicals on the faces of the test sample. The contaminants shall be either wiped or sprayed onto the coated faces of the test sample. Any tackiness, crazing or apparent loss of transparency shall be cause for rejection. After immersion, a change in percent haze greater than five, as measured by Test 17 on ANSI Z26.1, shall be cause for rejection.

9. Adhesion of the Coating Materials

a. The abrasion resistant coating materials shall retain adhesion to the substrate materials when subjected to Test Number 10, Article 5.10, of ANSI Standard Z26.1. The coating shall also pass a standard cross cut adhesion test. This test consists of scribing a grid of four horizontal and four vertical 1-inch long lines through the coating with a sharp steel blade. Pressure sensitive tape, Scotch brand Number 335-2, is then pressed firmly over the scribed area and is then pulled away at 90 degree angle to the sample sheet. The coating shall pass the test if no coating is removed from the substrate material.

b. There shall be no detectable cracking of the coating as indicated by fine radial cracks at the point of impact when struck with 2½ ft.-lb. energy from a dart having a ½-inch radius tip. The impacted specimen shall be examined for radial cracks visible by transmitted light.

c. No detectable cracks in the coating shall develop when the specimen is strained 2%. Stress may be applied by imposing 6,000 psi loading, using a tensile testing machine.

10. Dimensional Tolerance

a. The overall dimensions of individual units as supplied shall be within 0.030-inch of the nominal dimension specified. The thickness of the plastic materials shall be within a tolerance of + 5% of the nominal thickness.

11. Flatness

    a. When an individual light is placed on a truly flat surface, such as a surface plate, the material shall not indicate a bow of more than 0.031-inch per linear foot in any direction.

12. Edge Work

    a. All edges shall be straight and perpendicular to the surface, and shall be sawed or routed and reasonably free of burrs in order to prevent cutting of the rubber glazing strips. Sharp corners shall be removed around the entire periphery.

13. Optical Quality

    a. Optical quality of the plastic glazing materials shall be in accordance with Test Number 15, Article 5.15.2.2, of ANSI Z26.1. Under the specified procedure, no light and dark patches, existent over the entire area, shall appear in the shadow of the unmasked area of the specimen before the specimen shall have been moved a distance of at least 14-inches from the screen.

    b. Protective covering or other means shall be marked to permit orientation of extrusion grain for most favorable results at installation. This extrusion grain axis shall be horizontal in the installed light.

14. Material Quality

    a. Foreign Material and Inclusion Defects

        i. Less than 0.009-inch – allowed without population limit to the extent that they do not constitute a severe defect such as clustering.

        ii. 0.010-inch to 0.019-inch – allowed up to 10 per square foot average over the area of the light.

        iii. 0.020-inch to 0.050-inch – allowed up to three per square foot average over the area of the light.

        iv. 0.051-inch to 0.065-inch – allowed one per square foot average over the area of the light.

        v. 0.066-inch to 0.150-inch – allowed one per edge, only in the outer 25% of the light.

        vi. 0.151-inch and above – shall be cause for rejection.

        vii. Note: There shall be no black speck clusters of three or more above 0.019-inch in a 1-inch diameter circle.

        viii. Defects occurring in those areas of the lights which shall be covered by the glazing strips shall not be cause for rejection.

    b. Fibers and Scratches

i. Fibers and scratches less than 0.060-inch in length are allowable without population limit to the extent that they do not constitute a severe defect such as clustering.

ii. Fibers and scratches from 0.060-inch to 0.125-inch in length are allowed up to a maximum of two per square foot average over the area of the light.

iii. Fibers and scratches from 0.126-inch to 0.250-inch in length are allowed up to a maximum of one per square foot average over the area of the light.

iv. Fibers and scratches greater than 0.250-inch in length are not allowed.

v. Fine scratches which are detectable only when viewed in bright back lighting are acceptable.

c. Bubbles

i. There shall be no clusters of bubbles, no chain bubbles and no bubbles larger than 0.030-inches in diameter.

ii. Bubbles 0.020-inch to 0.030-inch in diameter, if present, shall have a minimum separation of 3-inches.

iii. In any 2-inch diameter area of glazing material, there shall be a maximum of 4 bubbles in the 0.011-inch to 0.020-inch diameter range.

d. Apparent Runs

i. 0.125-inch and under – allowed without population limit to the extent that they do not constitute a severe defect such as clustering.

ii. 0.126-inch to 0.250-inch – allow four per square foot average over areas of light but not to the extent that they constitute a severe defect.

iii. 0.251-inch to 0.500-inch – allow one per square foot, providing it does not constitute a severe defect.

iv. 0.501-inch to 1.00-inch – allow one per edge only in the outer 25% of light area.

v. 1.01-inch or above – shall be cause for rejection.

e. Orange Peel

i. “Orange Peel” in the surface shall be cause for rejection of the material if it exceeds the standards to be established between the Contractor and the Authority prior to manufacture.

f. Quality Assurance

i. The Contractor shall be responsible for the performance of all inspection and test requirements. Except as otherwise specified, the Contractor may utilize

the facilities of its supplier or any approved commercial laboratory.

g. Shipping

i. The material shall be carefully prepared for shipping and shall be properly protected to prevent damage. If a pressure sensitive masking is used, it shall be easily stripped from the material and not leave a gummy or sticky residue.

h. Identification

i. Each light shall be marked for identification in accordance with the requirements of ANSI Z26.1, Section 7 and 49 CFR 223 by the supplier in legible letters 0.1-inch high in the lower right hand corner as viewed from the inside of the vehicle. This identification shall be no closer than ¾-inch to the edge. The identification shall give the product name, the manufacturer, the serial number, and FRA Type I or II designation. Marking shall be legible and permanent for this application and shall be applied in such a manner so as not to reduce the integrity of the coating. The light shall be installed so that the marking can be read from the inside.

ii. The protective covering or other means shall be clearly marked with at least 1 inch high letters "THIS SIDE OUT" to indicate correct application of glazing with respect to protective coating. Location of these markings must be visible for identification after installation.

i. Documentation

i. The Contractor shall certify that the shipped material complies with the requirements in the Specification.

21.11 PANELS

A. General

1. Sandwich panels include, but are not limited to, plymetal, honeycomb, or lumber-core panels, with metal or other approved facing material.

2. Melamine, high pressure laminates used in the construction of the vehicle shall be two-ply laminated and shall consist of a hard plastic film facing permanently bonded to base sheet.

3. Contact adhesives shall not be used to bond the melamine to the base.

4. The final laminate assembly shall comply with NEMA LD-3, General Purpose Type, and comply with the Flammability, Smoke Emission & Toxicity section of this Specification.

5. Sandwich panels shall be fully balanced in construction

B. Honeycomb

1. When finished, continuous edge reinforcement shall be incorporated if needed to facilitate transfer of stresses and to seal edges against moisture penetration and other

damage. Where mechanical fasteners are used, threaded inserts shall be bonded into

2. The term honeycomb panel as used in these Provisions refers to honeycomb material bonded to melamine or to metal.

3. Honeycomb-core panels shall comply with applicable requirements of MIL-C-7438G, and MIL-HDBK-349, unless otherwise specified.

4. Bonding between the base material and the cover shall be sufficient to develop the full strength of the honeycomb material. The Contractor shall demonstrate by test and analysis that the honeycomb panel design selected for a particular application is adequate for the intended purpose.

C. Plywood

1. All "plywood" shall be manufactured to conform to the requirements of Grade-Structural I of the latest issue of American Plywood Association Specification APA PS1 and then stored under cover.

2. All plywood panels shall be sealed with aluminum lacquer on all edges and cutouts as soon as possible after fabrication.

3. All exposed edges of the panels, joints between panels, fastener heads, and openings of panels shall be waterproofed and sealed in an provided manner at the time of application.

4. Each plywood panel shall be formed from one piece. Jointed panels shall not be allowed.

5. Plymetal panels shall also meet the test criteria in **Figure 21-1**:

Figure 21-1: Plymetal Test Criteia

Minimum Metal to Wood Test*	**Minimum Value**
Dry Shear	250 lbf/in^2 (1.72N/mm^2) to 80% wood failure
Boil shear, 3 hrs boil, tested at 68°F	150 lbf/ in^2 (1.03N/mm^2) to 80% wood failure
Wet shear, 48 hrs. soak, 68°F	150 lbf/ in^2 (1.03N/mm^2) to 80% wood failure
Creep, under static load for 48 hrs, 68°F	250 lbf/in^2 (1.72N/mm^2) to 80% wood failure
* the plymetal test reference refers to inactive standard MIL-P-8053.	

D. Panel Flatness

1. The overall flatness shall not exceed a maximum deviation of 0.015" per lineal foot, with a maximum of 0.125" deviation of any point on the panel measured from a reference plane taken from any three corners. The overall deviation of the panel thickness shall not exceed 0.031" (1/32")

E. Phenolic Composite Floor Panels

1. Phenolic composite floor panels shall be designed to withstand the following physical requirements with no visible or audible indications of delamination of the panel skin from the core, and permanent deformation of the top surface shall be less than 0.010-inch

unless otherwise specified. There shall be no puncture or damage to fibers of the top surface. There shall be no separation of any internal core from the top or bottom skin. There shall be no fracture of the core. All test results are required to be submitted to the Authority for approval.

a. Indentation Resistance – The floor panel shall withstand a concentrated load of 300 pounds applied to a test dowel that has an overall 0.375-square inch surface area, with a 0.0625-inch radius on bottom edge of test dowel.

b. Static Load Test – Average Loading – A representative sample section of the flooring (without rubber floor covering attached) shall be supported on beams spaced at the maximum spacing used on the locomotive using production bonding and fastening techniques. A uniformly distributed load approved by the Authority shall be applied to both sides of the joint (butt and/or shiplap). There shall be less than 0.088-inch deflection.

c. Static Load Test – Maximum Loading – Using the identical floor panel-mounting configuration as described above, a uniformly distributed load of 200 lb. /ft² shall be applied to both sides of the joint (butt or shiplap).

d. Small Area Static Load Test – Using the identical floor panel mounting configuration as described above, a 300 pound load shall be applied to a 1-inch x 3-inch contact area directly over the mid-span, 6-inches from the outer carbody sidewall edge. The footprint shall be machined flat within 0.010-inch and the edges shall have a radius of not more than 0.125-inch. There shall be less than 0.200-inch deflection as a result of the load applied.

e. Small Object Impact Test – Using the identical floor panel mounting configuration as described above, a 16-pound standard bowling ball shall be raised directly over the mid-span, 24-inches from the edge of the panel and dropped from height of 60-inches. Permanent deformation of the top surface shall be less than 0.063-inch. Some core damage and some skin separation, radiating outward in a circular pattern with a maximum radius of 6.5-inches from the center of impact shall be allowed.

f. Large Object Impact Test – Using the identical floor panel mounting configuration as described above, a 150-pound load shall be dropped from a height of 12-inches upon a 3-inch x 8-inch contact "footprint" pad located directly over the mid-span, 24-inches from the edge of the panel. The "footprint" pad shall have a rubber pad on the downside surface with a Shore D 70 minimum. The pad shall have a 1-inch thickness machined flat within 0.060-inch with edges having a radius of not more than 0.030-inch. Permanent deformation of the top surface shall be less than 0.030-inch. Some core damage and some skin separation shall be allowed in a 6.5-inch diameter area.

g. Rolling Load Test – Using the identical floor panel mounting configuration as described above, a four-wheeled cart with a load of 200 pounds per wheel shall be rolled on the panels laterally, longitudinally and in a circular path with a 2-foot radius. The wheels shall be 3-inches in diameter, 1-inch wide with a 0.125-inch radius on each edge with a Shore A durometer of 80.

21.12 FIBERGLASS-REINFORCED PLASTIC

A. General

1. Fiberglass-reinforced plastic (FRP) shall be a laminated material, consisting of a gel coated surface and a combination of reinforced fibers in a thermoset polymer resin matrix, where the reinforcement has an aspect ratio that enables the transfer of load between fibers, and the fibers are chemically bonded to the resin. FRP shall withstand, without any physical deformation or structural damage, the environmental conditions in Part 1.06, and be resistant to acids, alkalis, and cleaning solutions recommended by the Contractor or used by the Authority.

2. FRP shall be manufactured by an open molding or matched die molding process. Production techniques shall ensure that the glass fiber reinforcement is uniformly distributed throughout the final product in such a manner as to avoid resin-rich or resin-starved sections. An analysis shall be performed to confirm that the proposed construction method, glass content and laminate structure is adequate for its intended purpose and meets the strength requirements provided in the Specification. If Tedlar is applied to exposed interior surfaces, it shall be applied using the in-mold process.

3. FRP parts shall have a minimum thickness of 0.125 inch and shall have a greater thickness at attachment points and edges. If fasteners are used to attach and/or assemble FRP parts, the parts shall be reinforced in a manner approved by the Authority to preclude the development of cracks. Exposed sharp edges shall not be allowed on any parts.

B. Construction

1. Resin

a. The resin shall be of good commercial grade, thermosetting, polyester, phenolic, vinyl-ester, or acrylic material selected to meet the physical properties of the Specification and molding process requirements.

2. Reinforcement

a. The fiberglass reinforcement shall be mat, fabric, woven roving, continuous roving, spun roving, or swirl mat as required to meet the physical properties of the Specification and the molding process requirements. The proposed glass content shall be a minimum 20% by weight, and shall be confirmed through testing to ASTM D 2584.

3. Gel Coat

a. A gel coat shall be provided on all finished surfaces of FRP. The gel coat shall be resistant to scuffing, fire, weather, and cleaning agents. The gel coat shall have a minimum thickness of 0.016-inch and a maximum thickness of 0.030-inch. If the surface of the FRP panel is to be painted, a primer gel coat shall be used and the part shall be painted in accordance with the Specification. If the FRP panel does not receive paint, then the gel coat shall be pigmented to match the color scheme selected by the Authority.

b. Finished gel coated surfaces shall have a minimum gloss value of 85 when measured with a 60° glossometer and shall exhibit no print through of the reinforcements or

have any appreciable orange peel.

4. Additives

   a. Additives, fillers, monomers, catalysts, activators, pigments, fire retardants, and smoke inhibitors shall be added to the resin mixes to obtain finished products with the required physical, flammability, and smoke emissions characteristics of the Specification.

   b. Antimony trioxide is prohibited as a component.

C. Strength Requirements

1. Independent laboratory test reports of production items shall be provided confirming that the production reinforced plastic material complies with the requirements of the following standards. The sample tested must be from a final production part and not simply the base laminate material. Test specimens shall be conditioned in accordance with ASTM D 618.

Figure 21-2: Fiberglass Reinforced Plastic Strength Requirements

Mechanical Property	**Test**	**Class I**	**Class II**
Tensile Strength	D 638	10,000 lbf/in^2	18,000 lbf/in^2
Compressive Strength	D 695	18,000 lbf/in^2	24,000 lbf/in^2
Flexural Strength	D 790	15,000 lbf/in^2	30,000 lbf/in^2
Impact Strength	D 256	10 foot pounds per inch of notch	13 foot pounds per inch of notch
Hardness		45 Barcol	45 Barcol
Class I: Items which are non-structural or shall not be exposed to any loads such as window masks, destination sign shrouds, ceiling cove panels, ceiling headers, etc. Class II: Items which are structural or shall be exposed to loads from crew or impacts such as end bonnets, under floor equipment enclosures, door pocket panels, wainscot panels, toilet room modules, toilet shrouds, seat back shrouds, windscreens, stair wells, etc.			

21.13 SEAT CUSHION

A. General

1. Cab seat cushion fill material shall be low-smoke flexible foam constructed of inherently fire-retardant materials. The thickness shall be subject to approval during design review. The material shall have a polymerized or vulcanized homogeneous (free from foreign material) cellular structure with a porous surface and open cells. The cells shall be interconnecting and uniform in size. Cellular material may be molded in one piece or may be assembled by laminating to achieve the required thickness. Laminated cushions shall be bonded together. Cushion material shall be properly cured to prevent any objectionable odor.

B. Physical Properties

1. Non-Silicone Foam

a. Non-silicone flexible low smoke foam shall meet the following physical property criteria when tested without upholstery material:

i. Tensile Strength – 12.0 lbf/in² minimum when tested to ASTM D 3574 Test E

ii. Elongation – 150 percent minimum when tested according to ASTM D 3574 Test E

iii. Compression Set at 50 percent – A maximum of 10 percent when tested according to ASTM D 1055

iv. Flex Fatigue – Thickness loss 5 percent maximum when tested according to ASTM D 1055

v. Tear Strength – 2.0 lbf/in² minimum when tested according to ASTM D 3574

2. Silicone Foam

a. Silicone foam shall meet the following physical property criteria when tested without upholstery material:

i. Tensile Strength – 15 lbs. /in² minimum when tested to ASTM D 3574 Test E

ii. Elongation – 100 percent minimum when tested according to ASTM D 3574 Test E

iii. Compression Set at 50 percent – A maximum of 10 percent when tested according to ASTM D 1056

iv. Flex Fatigue – Thickness loss of 5 percent maximum when tested according to ASTM D 1055

v. Tear Strength – 2.0 lbf/in² minimum when tested according to ASTM D 3574

21.14 SEAT UPHOLSTERY MATERIAL

A. Cloth Fabrics or Leather

1. General

a. Where specified or permitted, cloth fabrics used for seat upholstery shall be made of woven, transportation grade fabrics of wool, wool/nylon blend (90/10, 85/15), or an approved flame-resistant polyester. The maximum fabric shrinkage shall be 2 percent in either the warp or fill direction.

2. Physical Properties

a. Wool/Nylon Blend

i. Wool/nylon blend seat upholstery material shall be subjected to the physical tests of textile products required by the latest revision of the following ASTM methods, and the results shall not be less than the following values:

Figure 21-3: Wood/Nylon Blend Fabric Physical Property Requirements

Test Number	Description	Criteria
D-3776	Fabric Weight	15.5 oz/sq yd without back coating
D-3775	Fabric Count	Warp – (ends) 88 epi Fill – (picks) 40 to 72 ppi
D-5034	Breaking Strength and Elongation	Warp – 200 lbs Fill – 200 lbs
D-2261	Tear Strength (Tongue)	Warp – 20 lbs Fill – 20 lbs
D-4034	Yarn Slippage	Warp – 30 lbs Fill – 40 lbs
D-3597	Color Fastness	Water – Class 4 minimum Solvent – Class 4 minimum Crocking – Class 4 minimum Light – Class 4 minimum
D-4966	Martindale Abrasion Test	20,000 cycles – no breaks

b. Polyester

i. Flame-resistant polyester seat upholstery material shall be subjected to the physical tests of textile products required by the following ASTM methods, and the results shall not be less than the following values:

Figure 21-4: Polyester Fabric Physical Property Requirements

Test Number	Description	Criteria
D-3776	Fabric Weight	12 oz/sq yd without back coating
D-3775	Fabric Count	Warp – (ends) 88 epi Fill – (picks) 40 to 72 ppi
D-5034	Breaking Strength and Elongation	Warp – 270 lbs Fill – 200 lbs
D-2261	Tear Strength (Tongue)	Warp – 20 lbs Fill – 20 lbs
D-4034	Yarn Slippage	Warp – 75 lbs Fill – 65 lbs

D-3597	Color Fastness	Water – Class 4 minimum Solvent – Class 4 minimum Crocking – Class 4 minimum Light – Class 4 minimum
D-4966	Martindale Abrasion Test	20,000 cycles – no breaks

c. Fabric-Backed Vinyl

i. General

(a). Where specified or permitted, vinyl used for seat upholstery shall be made of woven transportation grade fabric-backed vinyl with a minimum weight of 22.75 ounces per square yard.

ii. Physical Properties

(a). Fabric-backed vinyl used for seat upholstery shall be subjected to the physical tests of textile products required by ASTM and the results shall not be less than the following values:

Figure 21-5: Fabric-Backed Vinyl Fabric Physical Property Requirements

Test Number	Description	Criteria
D751	Tensile Strength	Warp – 80 lbs Fill – 90 lbs
D751	Seam Strength	85 lbs
D751	Tear Strength (Tongue)	Warp – 6 lbs Fill – 7 lbs
D1117	Tear Strength (Trapezoid)	Warp – 18 lbs Fill – 20 lbs
AATCC-16A	Colorfastness – 200 hrs	No change
D751	Adhesion of Coating	10 lbs
Wyzenbeek 100k rubs #8 duck	Abrasion Resistance	No significant wear

21.15 RUBBER FLOOR COVERING

A. General

1. Rubber floor covering shall contain a minimum of 38 percent (nominal, by weight of compound) Butadiene Styrene rubber, shall be non-staining, non-discoloring, and 100 percent non-oil extended. Only high quality, fine, hard clay shall be used as filler. No whitening (limestone) shall be used in the compound. The rubber shall be free from

reground rubber, natural rubber, or coarse fillers.

2. At 68ºF, the rubber flooring shall bend 180 degrees around a ¾-inch diameter mandrel without breaking, cracking, crazing, or showing any change in color. The rubber flooring material shall be fully homogeneous throughout and shall meet the requirements of ASTM F 1344.

B. Inspection Criteria

1. Thin-Skinned Blister

a. A thin-skinned blister is a blister which, when finger pushed, shall collapse upon itself. Any thin-skinned blisters which exceed the limits listed below shall be cause for rejection of the floor sheet.

i. Maximum Size – 0.030-inch high, 0.80-square inch area with longest dimension of 2-inches.

ii. Maximum Population – three blisters in a 12-inch x 12-inch area with only one other blister within 3 feet of this area.

b. Repair Method – using a hypodermic needle, apply just enough Super Bond 420 or Bostik 1685 or equivalent, compress the blister and bring to a flush surface.

2. Thick-Skinned Blister

a. A thick-skinned blister is a blister which, when finger-pushed, shall collapse and then returns to its original condition.

i. Maximum Size – 0.030-inch high, 0.80-square inch area with longest dimension of 2-inches.

ii. Maximum Population – three blisters in a 12-inch x 12-inch area, and only one other blister within 3 feet this area.

b. Repair Method – no repair authorized, not an acceptable condition.

3. Lump

a. A lump is a blister without a void, consisting of solid material.

i. Maximum Size – 0.030-inch high, 0.80-square inch area with longest dimension of 2-inches.

ii. Maximum Population – three 12-inches x 12-inch area, and only one other lump within 3 feet of this area.

b. Repair Method – no repair required.

4. Hole

a. A hole is a defect which is 50 percent or more through the material. Any holes found

in the floor sheet shall be cause for rejection of the sheet.

5. Thin Area

   a. A thin area is a defect where the sheet is of reduced thickness locally.

      i. Maximum Size – 0.030-inch deep at the lowest point, 3 square inches with the longest dimension of 5-inches.

      ii. Maximum Population – one thin area in a 40-inch x 40-inch area, and no other thin area within 3 feet of this area.

   b. Repair Method – rub with #00 steel wool to blend this area into the normal thickness material and then buff to a normal surface finish.

6. Color Distribution

   a. Color distribution is an appearance judgment and shall be subject to the approval of the Authority. If the base coloring is not within 5 percent between production runs or the coloring is not consistent over the entire surface, the roll shall be rejected.

21.16 PAINTS AND COATINGS

A. General

1. The painted portion of the carbody, or any of its components, shall be sandblasted and painted as required by the Specification.

2. Austenitic stainless steel portions of the carbody shall not be painted, unless otherwise approved by the Authority for cosmetic reasons.

3. Where stainless steel is painted, procedures shall be as recommended by the paint manufacturer for the application, and surfaces shall be properly prepared to ensure adhesion.

4. All painting on the carbody or any component shall be performed in accordance with the paint manufacturer's recommendations.

5. To the greatest extent possible, all exterior paint application for a given vehicle shall use the same paint batch to assure uniformity of appearance.

6. The Contractor and its paint supplier shall submit a touch-up procedure and assure that a continuing supply of touch-up paints in colors used on the locomotive, suitable for spot application by spray, roller, or brush, shall continue to be available in the United States.

B. Materials and Preparation

1. Before painting any locomotive surface that is exposed to view, all dents, gashes, nicks, roughness, or other surface imperfections or depressions shall be removed, in so far as possible, by straightening and shall then be properly prepared to receive a filler material.

   a. These surfaces shall be properly cleaned and wash primed following straightening.

b. Any remaining dents or other surface imperfections shall then be filled with approved filler and sanded smooth.

i. The maximum allowable filler thickness shall be as recommended by the filler manufacturer for the environment and service to which it is to be exposed, but in no case shall it exceed 0.125-inch.

ii. If the filler material is provided by a manufacturer other than the manufacturer of the paint system, a letter from the paint manufacturer shall be required stating that the filler is compatible with the paint system.

2. Preparation of the substrate surface and application of painting materials by roller, brush, or spray shall be in accordance with the paint manufacturer's recommendations.

3. Only primers recommended and approved by the paint manufacturer shall be used.

4. All paint materials shall be used at the consistency recommended by the paint supplier. If thinners are necessary, they shall be approved by the paint manufacturer and shall be used only to the extent recommended.

5. Painting shall be performed by experienced labor, using proper equipment under competent supervision following documented and approved procedures.

6. Painting materials for all surfaces shall provide a high quality finish resistant to corrosion, chipping, fading, and shall retain the gloss level.

a. The coating shall be a two-part, high solids, low VOC, polyurethane paint system.

b. All components of the paint system shall be provided by the same manufacturer.

c. All paint and filler materials which are to be superimposed to form a finish system shall be mutually compatible and shall be warranted for use as a system by the manufacturer of the components.

7. Metal portions of the carbody not constructed of austenitic stainless steel shall, after fabricating, be prepared for painting by grit blasting and immediately painted with an approved epoxy primer, or washed with an alkaline solution, properly rinsed, phosphate coated, or painted with a coat of wash (etch) primer, and then coated with an approved epoxy primer.

8. All undercar metal, except stainless steel, shall receive a polyurethane finish as specified above.

a. The exterior finish shall have a gloss level of 85 +/- 5 as measured with a 60 degree Glossometer.

b. The supplier shall submit color samples and corresponding gloss and tri-stimulus values for approval.

9. Alternate paint systems, such as base coat-clear coat systems, or direct-to-metal paint systems may be considered by the Authority if the paint performance equals or exceeds that of a two-part polyurethane paint system.

10. Materials shall not be used past their recommended shelf life.

C. Exterior Painting

1. All exterior surfaces that are to be painted shall be prepared as specified, and the paint shall be applied according to the paint manufacturer's recommendations.

2. The paint shall be uniformly applied over all surfaces to be covered and shall be free from runs, sags, or other application defects.

3. Painting shall be performed in a clean, dry atmosphere at an ambient temperature as recommended by the paint manufacturer.

4. The final painted surface shall be tested on the first locomotive to the following criteria:

a. Hardness

i. All exterior paints shall be Imron or equivalent

b. Adhesion

i. Adhesion shall be tested per ASTM D 4541 and achieve a minimum rating as provided by the paint manufacturer. To avoid a destructive test of a vehicle's surface, which would require the tested surfaces to be repaired, the use of a test structure for this test may be proposed for consideration.

c. Thickness

i. The minimum and maximum dry film thicknesses shall be provided by the paint manufacturer. Dry film thicknesses beyond the manufacturer's recommendations shall not be accepted. Non-destructive testing shall be performed to verify final dry film thickness.

d. Paint Cure

i. A solvent rub test shall be performed per ASTM D 5402. The test procedure requires no less than 50 double finger rubs with a cloth wetted in acetone or methyl isobutyl ketone to the painted surface. No paint color shall transfer to the cloth. After 72 hours, the painted surface must retain all original gloss and hardness characteristics.

D. Apparatus and Underfloor Equipment

1. All underfloor- and overhead-mounted apparatus (motors, control boxes, junction boxes, brake valves, and other equipment as specified) shall be primed and painted in accordance with the following requirements unless otherwise indicated. All other apparatus shall be painted in an approved color.

2. The exterior surfaces of undercar equipment enclosures and apparatus made from carbon steel, other than propulsion control equipment, shall be prepared, primed, and painted, as specified.

3. The interior and exterior surface of all electrical equipment enclosures shall be coated with an approved insulating, thermosetting, resin-based, powder coating or polyurethane paint system.

    a. The interior of the boxes, including insides of covers, shall be white and the exteriors shall match the undercar paint scheme.

4. Parts of undercar equipment enclosures made from plastic or fiberglass shall be painted in accordance with the above requirements for metal portions, except that the paint system shall be compatible with the plastic used and an insulating coating need not be applied.

E. Painting Restrictions

1. Any equipment or parts of equipment which can be damaged or suffer impaired operation from painting shall not be painted and shall be corrosion resistant.

2. The following items shall not be painted:

    a. Copper tubing, piping, and fittings;

    b. Wearing surfaces;

    c. Couplers, including yoke and draft gear;

    d. Wire and cable;

    e. Power resistors;

    f. Heat transfer surfaces;

    g. Electrical insulators;

    h. Elastomeric parts;

    i. Grounding pads; and

    j. Conduit and fittings.

3. The following truck-related items shall not be painted, unless approved by the Engineer:

    a. Wheels;

    b. Axles;

    c. Elastomeric parts;

    d. Grease fittings;

    e. Linkages;

    f. Threaded adjustment parts;

g. Electrical equipment; and

h. Wearing Surfaces.

F. Interior Painting

1. All exposed interior surfaces, including molding and trim, shall be as specified. Interior surfaces requiring painting shall be coated with an approved painted finish. Parts which are to be painted shall be cleaned and prepared in accordance with the recommendations of the paint manufacturer.

2. The Contractor and its paint manufacturer shall provide a touch-up procedure and assure that a continued supply of touch-up paint in the proper colors suitable for spot application shall continue to be available in the United States.

G. Corrosion Protection

1. The design of the vehicle shall avoid the trapping and retention of water and debris.

2. All surfaces shall be completely free of rust, scale, grease and other foreign matter immediately preceding the application of the primer.

3. All joints shall be properly sealed with an approved waterproofing compound that will be compatible with the coatings applied.

4. All surfaces that are concealed after assembly shall be properly cleaned and coated with an approved preservative coating in a manner recommended by the coating manufacturer, especially inside surfaces of fabricated items.

5. Where possible, dip coating of sections is preferred.

6. Any arc welding performed on stainless steel shall be thoroughly cleaned and, if necessary, coated with an approved stainless steel coating material.

7. All aluminum surfaces, where required, shall be properly cleaned and shall be given a coating of an approved zinc chromate material.

8. All joints between aluminum and other metals shall be suitably waterproofed and insulated with an approved compound which shall cover the entire area of each contact surface and conduct heat, if necessary.

9. Aluminum heat transfer surfaces shall be anodized. If approved by the Engineer, heat transfer surfaces may be irridite to Military Specification MIL-C-5541E, Class 3, followed by priming and painting, provided that this treatment can demonstrate corrosion protection equivalent to anodizing.

H. Powder Coatings

1. Powder coating materials are to be epoxy based or approved equal as recommended by the powder coating manufacturer for the specific application. The coating shall have a finished thickness between 1.5 and 2.5 mils.

2. The surface to be powder coated shall be prepared in accordance with the powder coating manufacturer's published recommendations.

3. Powder coated parts which are scratched during handling and installation shall be touched up using a matching color epoxy paint that is allowed to cure prior to installation.

4. Epoxy based powder coatings of middle to high gloss level shall have a minimum impact strength of 120 inch-pounds when tested in accordance with ASTM D 2794

I. Acoustic Insulation

1. Acoustic insulating materials shall be applied to properly cleaned underframe, sides, ends, roof and floor sheets, in accordance with the supplier's recommendations. The materials shall be resistant to dilute acids, alcohols, grease, gasoline, aliphatic oils, and vermin. The material shall be unaffected by sunlight and ozone and shall not become brittle with age. It shall be Daubert Chemical Company's V-Damp 3680 sound deadening compound, 3M Corporation's 2552 Damping Foil or approved equal.

J. Paint Process Documentation

1. The Contractor shall prepare detailed paint coating and application documentation containing manufacturer's product data sheets, procedures for surface cleaning and preparation, priming, surfacing, and painting for the carbody and all equipment that is to be painted or powder coated, as well as touch-up and repair procedures.

2. A detailed paint schedule showing the equipment painted, paint type and manufacturers' recommendations for thickness, and other pertinent parameters shall also be included. This document shall be submitted for approval prior to painting of any surfaces or components and shall be made part of the maintenance manuals.

K. Truck Painting

1. All truck components to be painted shall be given a full coat of primer prior to assembly.

2. Following assembly, all exposed surfaces of each truck, including machined mounting surfaces not used, shall be cleaned with compressed air and solvent wiped to remove all dirt and grease. These surfaces shall then be sprayed with one coat of an approved black truck paint of a type which shall not conceal cracks that may develop in service, and air-dried.

3. Wheels, axles and exposed rubber parts shall not be painted.

L. Decals

1. Preparation and application of decals shall be in accordance with the decal supplier's recommendations.

2. Where appropriate, decals may be embedded in the paint system and shall be processed so as not to void any warranties from the paint or decal manufacturers.

3. Edge seal shall be used on applications where the decal is not embedded in the paint to protect the decal and its adhesive from cleaning solutions and automatic washing brushes.

4. Logo – A logo design shall be applied to the locomotive exterior in an area to be selected by the Authority. Logo design shall be furnished by the Authority. The Authority's logo shall be made of exterior type reflective decorative vinyl film, 3M "Scotchlite" or approved equal

5. Locomotive Numbers – The locomotive number shall be applied to the outside of the car bodies in areas to be approved and in a sequence also to be selected by the Authority. The Contractor shall submit side and elevation drawings to the Authority on which the Authority will indicate the lettering style and symbols desired

6. Reflectorization – Red high reflective tape with sealed and rolled edges shall be applied around the carbody sill

7. Contractor's Name Plate – Two permanent builder's plates shall be applied to the exterior of each locomotive. Plate size, wording and location shall be approved by the Authority. The ownership plate, if required, and Contractor's name plate shall be stainless steel, with etched and painted lettering

21.17 FLAMMABILITY, SMOKE EMISSION, AND TOXICITY REQUIREMENTS

A. General

1. The Contractor shall submit a Fire Safety Analysis Report for the Authority approval, in accordance with Part 26.00.

B. Combustible Content

1. The design of the vehicle shall minimize the total combustible material content of the vehicle. A matrix showing the total weight of all combustible materials, where used, flammability, smoke emissions, test identity, test facility, test requirements, test results, nature, and quantity of the products of combustion, caloric content, and peak heat release rate per ASTM E1354 shall be submitted by the Contractor during design review for the Authority's approval. All materials with a surface area greater than 16 in^2 shall be tested at a flux radiance of 50KW/m2. As a minimum, the following materials shall be tested: seating materials, wall coverings, window masks, fiberglass components, insulations, plymetal walls, floor covering, floor panels, non-metallic equipment boxes and covers, window glazing, lighting lenses and diffusers, window gaskets, door seals, HVAC in-air stream components, grills, door nosing, filters and, electrical wire and cable insulation.

C. Flammability and Smoke Emission

1. All new materials used shall be tested to demonstrate compliance with the requirements set forth in 49 CFR 238.103 and NFPA 130. The Contractor shall submit test reports for all materials tested and a summary table to the Authority for approval.

2. The Contractor shall test the cab floor assembly in accordance with ASTM E119 to demonstrate a 30-minute endurance rating. The test procedure, test facility, and test results shall be approved by the Authority prior to the Contractor's procurement of any flooring material necessary for vehicle production.

3. The test specimen shall be a full width vehicle section including side sills or that portion of the wall which extends below the floor. If approved, the exposed area may be reduced

to meet a length limitation imposed by the size of the test furnace, but the length shall not be less than that of the actual cab. No fewer than two (2) typical penetrations, spaced at a distance from each other no greater than that which shall exist in actual construction, shall be included in the test specimen floor splice configurations, any penetrations through the floor including but not limited to ventilation ducts, conduits, etc, and any areas of the floor that are thinner than the standard floor section. The specimen shall include typical floor splice configurations. Test specimen shall be loaded to approved loading conditions. The concentrated loads shall be applied to simulate underfloor equipment. The Test specimen shall include at least three typical transverse supports. The test specimen shall represent the actual construction utilized in production. This includes the floor covering, floor boards, floor structure, thermal and acoustical insulation, and floor pans.

4. The Conditions of acceptance for this test shall be those required for unrestrained assembly.

D. Toxicity

1. New Materials and products identified by state agencies, federal agencies, and the American Conference of Governmental Industrial Hygienists (ACGIH) as containing toxic properties or to emit toxic products of combustion in excess of the limits defined herein shall not be used. Materials and products generally recognized to have highly toxic products of combustion shall not be used.

2. All materials used in the locomotive construction, except for materials used in small parts such as knobs, rollers, fasteners, clips, grommets, and small electrical parts that would not contribute significantly to fire propagation or to smoke or toxic gas generation and are distributed throughout the locomotive, shall be tested for toxicity using Boeing Specification Support Standard BSS-7239. Alternative test protocols may be proposed for the Authority's consideration providing that the results are reported as noted below. Materials shall meet the following maximum toxic gas release limits (ppm) as determined per BSS-7239:

Figure 21-6: Maximum Toxic Gas Release Limits per BSS-7239

Carbon Monoxide (CO)	3,500 ppm
Hydrogen Fluoride (HF)	200 ppm
Nitrogen Dioxide (NO2)	100 ppm
Hydrogen Chloride (HCL)	500 ppm
Hydrogen Cyanide (HCN)	150 ppm
Sulfur Dioxide (SO2)	100 ppm

3. The tests shall be conducted in the flaming mode after 240 seconds using the NBS Smoke Density Chamber for sample combustion. The gas sampling may be conducted during the smoke density test. The test report shall indicate the maximum concentration (ppm) for each of the above gases at the specified sampling time and shall be submitted to the Authority for review and approval.

E. Electrical Fire Safety

1. Electrical equipment, wiring and apparatus shall conform to NFPA 130, Section 8, except where more restrictive requirements are imposed by the Specification.

21.18 PIPING AND TUBING

A. General

1. All piping valves, fittings, installation methods, and testing shall be in accordance with the EN and Code for Pressure Piping, ANSI B31.1. All joints shall be easily accessible. Piping and fittings that the Authority would expect to change shall be to ANSI B31.1. Other piping and fittings may be to EN standards and will be approved by the Authority on a case by case basis.

2. Following installation, all piping systems shall be cleaned to remove dirt, metal chips, oily contamination, and moisture. After cleaning, all piping systems shall be pressure tested in accordance with the latest edition of the Code for Pressure Piping, ANSI B31.1. All leaks shall be repaired and the system re-cleaned and retested until leak-free.

3. Pipes shall be supported throughout their length and at all connections to prevent vibration or noise and to limit stresses in the pipe to less than 50 percent of the pipe's fatigue endurance limit. Pipes and their connections shall not interfere with the removal of other components. Pipe routing and support shall be planned and accomplished in an efficient, organized manner to keep the total length and number of fittings and bends to an absolute minimum. All changes in direction shall be accomplished by bending the pipe to a radius of not less than that specified by AAR Specification Number 2518, Standard S-400. Direction-change fittings shall not be permitted in the trainline brake pipe or in the brake cylinder pipe. Support and clearances provided between adjacent pipes and between pipes and surrounding structure, equipment, or other appurtenances shall be sufficient to prevent chafing or contact due to any combination of locomotive loading and deflection, locomotive dynamics, and thermally-induced movement. The minimum clearance shall be 1/8-inch.

4. At all locations where pipe or tubing passes through holes in the floor, bulkheads, structure, or any fixed member, it shall be rigidly clamped to protect against possible damage or noise due to bearing, abrasion, or locomotive dynamics-induced rattling. Clamps shall not be welded, brazed or otherwise permanently fastened to any pipe or tubing. Pipe and tubing interfaces with clamps shall be insulated with an elastomeric or woven non-asbestos mineral fabric tape material to protect and sound-insulate the pipe or tubing.

5. Wherever carbody piping interfaces with vibration-isolated rotating equipment such as the air compressor and air conditioning compressor-condenser unit, approved flexible vibration eliminators shall be used. The pipe connection at either end of the flexible elements shall be rigidly clamped no farther than 2-inches from the flexible elements. All pipe clamps shall be inherently rigid and shall be firmly attached to locomotive structure. Cantilevered clamps or clamp supports that are weaker than service-proven designs shall not be accepted. All clamps shall be of a suitable material for the application.

6. Prior to commencing overhaul of the locomotives, the Contractor, in cooperation with the

manufacturers and suppliers, shall make a thorough analysis of the design of the pneumatic systems proposed for the locomotives to assure that every reasonable precaution has been taken in design and installation to prevent the locomotives from disablement in service as the result of adverse winter conditions. Before being granted permission to commence overhaul, the Contractor shall submit to the Authority the details of its analysis and of any special preventative measures it proposes to incorporate in the design. The design layout, installation, and hanging methods, etc., shall be jointly inspected and reviewed with and approved by the Authority.

B. Air Piping, Tubing, and Fittings

1. The main reservoir pipe and brake pipe shall conform to ASTM A53 or ASTM A106, Schedule 80 seamless pipe. Where ASTM A53 or ASTM A106 piping is provided, its application shall also comply in all respects to AAR Specification No. 2518, Standard 400, latest revision.

2. Type "K" annealed copper tube per ASTM B88, latest revision, or approved equal, may also be used, provided it is installed no lower than 2 inches below the floor sheet or structural member and is protected by means of equipment or approved steel guards from any potential impact damage from rail debris, especially in the truck and outboard of the bolster areas. Approved copper tube shall also comply with any relevant requirements of AAR Specification No. 2518. Where suitable protection in damage-prone areas is not possible or practical, approved steel or stainless steel piping sections shall be provided. All joints for copper tubing shall utilize fittings of wrought copper or non-porous cast brass in accordance with ANSI B16.22 and B16.18.

3. All air hoses shall conform to the requirements of AAR Specification M-618 with AAR approved reusable fittings meeting AAR Specification M-927.

4. All air piping must comply in all respects with the air brake supplier's design and installation requirements. The diameter of the main reservoir pipe and brake pipes shall meet the brake supplier's requirements; however, in no case shall these pipes be less than 0.875 inch outside diameter. All air pipes shall be sized in accordance with the function intended and may be either ASTM A53 or ASTM A106 schedule 80 pipe or seamless copper tubing as described previously.

5. Within one hundred-eighty (180) days of Contract Award and prior to overhaul of production locomotives, the Contractor shall provide the Authority with a report containing written approval from the air brake supplier of the Contractor's air brake piping fabrication, installation, and design concept. The following information shall be contained in the report:

   a. All critical line sizes and materials including the main reservoir pipe, the brake pipe, and the brake cylinder piping.

   b. The installation details of all critical lines including routing, total length and volume, elevation and slopes, and major joint and direction change locations. A list of all proposed bend radii shall also be provided.

   c. Pipe processing details including welding, brazing, cleaning, and fabrication methods.

d. Locations of all major air brake valves and controls, relay, and emergency venting devices, and the proposed location and volume of all reservoirs.

e. An air consumption analysis justifying the proposed air storage system design.

6. All air piping shall be installed in a manner to provide drainage away from devices, or branch pipes leading to devices, when the function of those devices could be impaired by the accumulation of water or ice.

7. All cut-out cocks shall be of the vented type, except where function prohibits. All cut-out cock handles and their arrangements shall be as described in this Specification.

8. Air piping on the trucks shall be 0.50 inch ASTM A53 or A106, Schedule 80, or approved equal. Low spots (traps) are strictly prohibited on the trucks. Truck piping shall not be run on the bottom of truck side frames, transom, or bolster, unless approved by the Authority.

9. Where steel piping is used, all connections and joints where disassembly for service may be required shall utilize swivel type butt-welded flange fittings with an "O" ring type seal. The use of threaded fittings is expressly prohibited. Approval may be granted for the use of threaded fittings in extreme cases where adequate proof is provided that flanged fittings cannot be used.

C. Air Conditioning System Piping, Tubing, and Fittings

1. Air conditioning refrigerant lines shall be of seamless copper tubing, ASTM B88 type "K" or type "L" or ASTM B280, with wrought copper sweat type fittings. Refrigerant lines below the upper surface of the floor or subject to damage during operation shall be ASTM B88, type "K" only. Condensate drain lines shall be seamless copper tubing, type "K" or seamless stainless steel tubing.

2. Joints shall be kept to a minimum and all inaccessible runs of tubing shall be without joints. Finned tubing in evaporators and condensers shall be copper. Instead of elbows, tubing may be bent utilizing a bending tool designed specifically for bending of the tubing to be used.

3. Suction lines shall be designed and installed without traps. The suction line shall be sized for 3 psi (gauge) maximum system pressure drop and the liquid line shall be sized adequately to prevent flashing due to pressure drop.

4. Lines subject to condensation shall be insulated with an approved insulation, applied with approved contact cement. The liquid line shall be insulated in all areas where required to provide additional mechanical or thermal protection. Insulation at all joints and fittings shall be mitered and sealed with an approved material. The insulation, adhesive, and sealant shall meet the Specification requirements for thermal, smoke emission, and flammability performance.

5. All piping and pipe subassemblies shall be deburred, cleaned, dried, and capped with tight fitting plastic caps, or approved equal on all openings after fabrication. Caps shall remain in place until immediately prior to incorporation into the final assembly.

6. Vibration eliminators shall be used in piping connections to the compressor unless

deemed unnecessary by the Authority. Tubing installations shall be designed so that ease of maintenance can be achieved, as approved by the Authority.

7. Tubing installations shall be designed to allow any single length of tubing to be replaced without dismantling or removing surrounding equipment, piping, wiring, or other appurtenances. This requirement does not apply to piping within a self-contained modular HVAC unit.

D. Brazing and Soldering of Piping, Tubing, and Fittings

1. All brazing and soldering shall comply with the applicable parts of **Part 21.04** and the following requirements:

a. All refrigerant piping and air system copper tubing shall be joined using silver solder conforming to Federal Specification QQ-B-654A, BAg-5 or BCuP-5.

b. Refrigeration piping and tubing shall be internally swept with a continuous flow of a non-oxidizing gas such as dry nitrogen during brazing.

c. Condensate drain tubing shall be joined using 95-5 solder or silver solder as above. Solder joints shall be wiped and have flux cleaned from tubing and fittings after soldering.

d. After fabrication, the refrigeration and air systems shall each be cleared of all dirt and foreign matter, flushed with a degreasing agent and dried, all according to a procedure prepared for each by the Contractor and submitted to the Authority for approval.

E. Water Piping and Fittings

1. Water piping shall be seamless copper tubing, type K, with sweat type fittings of wrought copper or cast brass. Piping shall be sloped to allow drainage. Low points in piping shall be equipped with automatic drain valves, Ogontz PP39FR or approved equal, which shall discharge all the water in the locomotive to the tracks whenever the water temperature in the locomotive falls below 38°F. Manual drain valves shall also be provided. Anti-freeze protection (heat trace tape) shall be provided for the water fill housings, associated underfloor water piping, water system drain pipes, water tanks, and the Ogontz valves.

F. Sewage Piping and Fittings

1. All waste piping lines shall be minimum 2 inch seamless stainless steel or cast iron tubing with welded type fittings of stainless steel Sharp angles are to be avoided and "sweep" fittings shall be no more than 45 degrees.

2. Cleanouts must be provided in areas where blockage might occur. Sewage piping should at all points slope with downward flow. Anti-freeze protection (heat trace tape) shall be provided for the sewage piping, tank, and all valves.

G. Pressure Vessels

1. All pressure vessels shall conform to the latest revision of Section VIII of the ASME Boiler and Pressure Vessel Code for Unfired Pressure Vessels. Test reports shall be

furnished for each pressure vessel, and each pressure vessel shall be stamped to document the test.

21.19 AIR FILTERS

A. HVAC and Equipment Ventilation Filter

1. Filters shall be selected in accordance with the manufacturer's recommendations for the specific equipment involved. All filters shall have an integral frame. Filters shall be the throw-away type, except reusable filters may be approved for specific applications where throw-away filters are not available. Filters shall be designed to meet the performance requirements of each installation, and shall be Authority-approved. All filters shall be freely accessible for maintenance.

B. High Pressure Air Filters

1. Air filter assemblies with replaceable filter elements shall be provided in the air line that connects each subsystem to the air supply system. The air filter filtering capability, flow rate capability, and overall size shall be appropriate for the application so that the filter replacement interval is greater than one year. It shall be possible to gain access to the filter element for replacement without requiring any pipe fittings to be disconnected or loosened. Filters shall be provided for each of the following systems and any others operated from the air supply system:

2. Glass fiber mat types of filter media shall not be used for high pressure or high volume applications.

    a. Each air brake control assembly,

    b. Input and output of each height control valve,

    c. Door operators (if pneumatic),

    d. Horn.

C. Low Pressure Air Filters

1. Replaceable media type filters shall use resin-bound, spun-glass fiber materials having an uncompressed thickness not less than 3-1/2 inches. It shall be non-absorptive of fluids and gases, shall be processed in such a manner that material density increases progressively from air inlet to air exit side, and shall be coated with not less than 24 grams per square foot of a dust-retaining, viscous adhesive film. This film shall be stable at temperatures up to 150°F. The filter medium shall be cut not less than ½ inch oversize to ensure adequate sealing between the edge of pad and its integral frame.

21.20 WIRE AND CABLE

A. General Requirements

1. The Contractor’s design and construction shall ensure that the minimum number of wire types and sizes shall be used in the vehicle.

2. Selection of wire sizes and insulations shall be based on the current carrying capacity, voltage drop, mechanical strength, temperature and flexibility requirements in accordance with applicable APTA, AAR, ICEA, ASTM, NEC, and MIL Specifications. However, in no case shall the properties of the wire and cable be less than those properties delineated in this specification. Extra-fine wire stranding shall be utilized on applications subject to repetitive motion.

3. All applications of shielded cable shall be subject to the approval of the Authority

4. The Contractor and each manufacturer of equipment through the Contractor shall submit to the Authority for approval samples at least 12 inches long, specifications, and 3 copies of certified qualification test documentation of each size and type of wire and cable specified before utilizing said wire and cable.

B. Conductors

1. Conductors for wire AWG No. 12 and smaller shall be soft, annealed nickel plated copper constructed in accordance with MIL-W-22759/6B. Conductors of all sizes insulated with irradiated, cross-linked polyolefin wire shall be soft, annealed tinned copper, in accordance with ASTM B33. Minimum stranding shall conform to AAR Standard S501, S502 (No. 589), or ASTM B-172 Class K, or ICEA S-66-524/NEMA WC7, Table L-7, Class K for AWG No. 10 or larger, as appropriate for the application.

2. Stranding and conductor construction for wire sizes AWG No. 12 to AWG No. 16 shall be in accordance with AAR Recommended Practice RP-585, ASTM B-174, Class K, or ICEA S-66-524/NEMA WC7, Table L-8, Class M, as appropriate for the application.

3. Stranding and conductor construction for wire sizes AWG No. 18 and smaller shall be in accordance with ASTM B-174 Class L or ICEA S-19-81/NEMA WC3, Table L-8, Class M, or shall be nineteen (19) strand construction as appropriate for the wire size.

4. The use of solid wire shall not be permitted except for approved wire wrap applications.

5. Wiring shall be sized for the intended load, voltage drop, installation method, and applicable codes. Calculations of wire sizes shall be in accordance with APTA-RP-E-009-98, "Recommended Practice for Wire used on Passenger Equipment." When the free air rating is used, the Contractor shall furnish data to show that the cables shall not exceed their rated temperature at the rated current. Wire ampacities shall be de-rated to meet the temperature requirements of all devices to which the wire connects. When short time ratings, short time overload temperatures, and thermal time constants are used to determine cable size, the parameters used shall be submitted for approval.

6. In no case shall wire smaller than the following sizes be used:

   a. Wire which is pulled through conduits or wire ways - AWG No. 14.

   b. Wire on electronic units, cards, and card racks - AWG No. 28.

   c. Wire within control compartments - AWG No. 18.

   d. A multi-conductor cable where current is not a factor in wire size selection - AWG No. 18.

e. All other wire, including that which is not pulled through wire ways and conduits - AWG No. 16.

7. The Authority may approve smaller wire sizes for selected applications upon submission of appropriate applicable data for justification.

C. Insulation

1. General Wiring Insulation

a. Teflon, mineral filled, abrasion resistant insulation may be used on wire sizes AWG No. 12 to AWG No. 28. Otherwise, for all general locomotive body wiring, the insulation shall be a flame retardant, flexible, irradiated cross-linked polyolefin material having a continuous temperature rating of 230º F. The insulation shall be rated at 2,000 VAC and VDC, in the case of wires carrying a nominal voltage greater than 150 VAC or VDC, and rated at 600 VAC and VDC, in the case of wires carrying a nominal voltage of 150 VAC or VDC or less. For wire sizes AWG No. 6 and larger, the insulation material shall be formulated for extra flexibility.

b. Insulation shall meet the following flammability requirements:

i. Cross-linked polyolefin shall be tested in accordance with test method ICEA S-66-524/NEMA WC7, Paragraph 6.12.5. After five (5) applications of fifteen (15) seconds each, with a three second rest period between applications, flame shall extinguish in ten (10) seconds or less.

ii. Other insulation materials shall be tested in accordance with IEEE-383.

2. Cross-Linked Polyolefin Wire Insulation

a. The irradiated cross-linked polyolefin wire insulation shall be constructed and tested in accordance with the following requirements:

i. Flexibility Tests for Cables

(a). Flexibility tests for cable sizes up to AWG No. 2/0 shall be performed in accordance with AAR Recommended Practice RP-585, paragraph 5.9.7.1, for the appropriate wire size.

(b). Flexibility tests for cable sizes AWG No. 2/0 and larger shall be performed in accordance with AAR Recommended Practice RP-585, paragraph 5.9.7.

ii. Single Conductor Thermal Overload Test

(a). A continuous current of 115 Amperes shall be applied to an 18 foot length of AWG No. 10 test wire in 77°F still air. A 3000C VDC potential shall be maintained between the test wire and an AWG No. 18 bare copper wire wrapped snugly around the outer insulation surface of the test wire. Failure shall occur when a short circuit is established between the bare copper wire and the test wire. Minimum time to failure shall be 3 minutes.

iii. Bundle Overload

(a). A bundle overload test using a 7 wire bundle shall be performed in accordance with AAR Standard RP585, paragraph 5.9.1.

iv. Temperature Cycling Tests

(a). This test shall be performed on an 8 foot length of AWG No. 10 wire with 2 kV insulation. Thermocouples shall be attached to the outer jacket surface, and on the conductor, under a small incision in the insulation approximately 12 inches from one end of the sample. Both ends of the sample shall be securely clamped using hose clamps.

(b). Prior to temperature cycling, the sample shall be conditioned for 2 hours at a temperature of 302°F.

(c). The sample shall then be temperature cycled between ambient of 257o and -22°F by transferring the sample between an air-circulating oven, set at 257°F and an air-circulating cold box set at -22°F. The time during which the sample stays in each chamber shall be sufficient to allow both thermocouples on the sample to read the same temperature as the environment.

(d). One cycle shall be defined as an approved dwell time at both 257°F and -22°F. The sample shall be subjected to a total of 250 cycles, with a visual observation at the end of each cycle for cracks and other damage. After 250 cycles, the sample shall be immersed in water for 6 hours with both ends out of the water, and then subjected to a dielectric test of 5 kVAC for 5 minutes and also examined by microscope to verify that no cracks exist.

(e). Flame-retardant, flexible, irradiated, cross-linked polyolefin insulation rated at 257°F may be used, provided that it meets the requirements of all the above tests and standards, modified to reflect the temperature rating related characteristics. The revised values, and the use of such wire, must be approved by the Authority. Cross-linked polyolefin insulation shall not be permitted for use on wires connected to heater elements or any other high-temperature device.

3. Other Wire Insulation

a. All insulation other than irradiated, cross-linked polyolefin shall meet the following test requirements, based on MIL-W-22759, and using the following parameters:

i. Dielectric

(a). Test per MIL-W-22759/10B (for 1,000 V wire with tests at 9.5 kV impulses) or MIL-W-22759/6B (for 600 V wires with tests at 8 kV impulses).

ii. Insulation Resistance

(a). Test per ASTM D-470. Minimum accepted value shall be 1,000 megohms per 1,000 feet, using a 1,000 VDC megohmmeter.

iii. Spark test

(a). One hundred percent of all single conductor cables and all single conductor cables being used in a multi-conductor cable shall be inspected by Impulse Dielectric Test or by chain electrode Spark Test. Spark Test Apparatus and Procedure shall be in accordance with MIL-W-22759. Spark Test voltages shall be equivalent to impulse test voltages by corresponding RMS value at 3 kHz.

Figure 21-7: Spark and Impulse Test Voltages

Impulse Test Voltage kV Peak	3 kHz Test Voltage kV RMS
8	5.7
9.5	6.7
10	7.1

iv. Air aging

(a). Test per ASTM D-638. Age sample for seven (7) days at 302°F in an air oven. Minimum tensile strength and elongation shall not be less than 85percent of the unaged values. Also test per IEEE STD 383-1974 and ASTM D-573 for extended life.

v. Cold Bend

(a). Test per NEMA WC3, except test temperature shall be -58°F.

vi. Weight Loss

(a). Weight loss of the insulation material shall not exceed one percent when subjected to an oven temperature of 266°F for 500 hours.

vii. Chemical Resistance

(a). An appropriate length sample shall be measured for insulation diameter and total weight to record initial values. The wire shall be immersed to within 3 inches of each end in the test fluid for 24 hours at 149° F. During the immersion stage, the minimum bend radius of the wire shall be ten (10) times the diameter of the wire being tested. Upon removal from the test fluid, the specimen shall be cooled to room temperature for 1 hour and the diameter gauged and reweighed for comparison with the original values. The maximum diameter and weight increase shall not exceed 30 percent. Typical fluids for this test include:

(1). Humble No. 2214 Railroad Diesel Lubricating Oil and lubricants (100 percent solution)* Humble Diesel 260 or Railroad T fuel oil (100 percent solution);

(2). Mineral oil (100 percent solution);

(3). Hydrochloric acid, nitric acid, sodium hydroxide, sulfuric acid (0.1 percent solution);

(4). Potassium hydroxide (0.1 percent solution);

(5). Petroleum distillates and other graffiti removers and cleaning compounds;

(6). Kerosene solvents (100 percent solution);

(7). Trisodium phosphate solution (50 percent solution);

(8). Skydrol 500 B hydraulic fluid (100 percent solution); and Water.

viii. Temperature Cycling Testing

(a). The test shall be performed on an 8 foot length sample of AWG No. 12 wire.

(b). Thermocouples shall be attached to the outer jacket surface and on the conductor under a small incision in the insulation about 12 inches from one end of the sample. Both ends of the sample shall be securely clamped using hose clamps.

(c). The sample shall be conditioned for 2 hours at a temperature of 302°F. The sample shall then be temperature cycled between ambient of 257°F and -22°F by transferring the sample between an air-circulating oven, set at 257°F and an air-circulating cold box set at -22°F. The time during which the sample stays in each chamber shall be sufficient to allow both thermocouples on the sample to read the same temperature as the environment.

(d). One cycle shall be defined as an approved dwell time at both 257°F and -22°F. The sample shall be subjected to a total of 250 cycles, with visual observation at the end of each cycle for cracks and other damage. After 250 cycles, the sample shall be immersed in water for 6 hours with both ends out of the water, and then subjected to a dielectric test of five (5) kVAC for 5 minutes and also examined by microscope to verify that no cracks exist.

ix. Single Conductor Thermal Overload Test

(a). A continuous current of 115 amperes shall be applied to an 18 inch length of AWG No. 12 test wire in 77°F still air. A 1,000-VDC potential shall be maintained between the test wire and an AWG No. 18 bare copper wire wrapped snugly around the outer insulating surface of the test wire. Failure shall occur when a short circuit is established between the copper wire and the test wire. Minimum time to failure shall be 3 minutes.

x. Seven-Wire Bundle Thermal Overload Test

(a). A 7 wire cable bundle shall be formed by twisting 6 insulated AWG No. 12 conductors around a center insulated AWG No. 12 conductor.

(b). A 120 Ampere current shall be passed through the center conductor for 7 minutes. After the test period, the cable bundle shall be examined for visible damage to the outer 6 conductors. Failure shall occur if any of the outer conductors split, rupture, or melt and adhere to the center conductor insulation.

xi. Qualification and Production Tests

(a). The tests required for this Specification concerning Qualification and Production shall be in accordance with tests in MIL-W-22759 for all lots produced.

(b). All test reports covering Production and Qualification tests shall be submitted to the Authority for approval with samples prior to any shipment of materials.

4. Wire Insulation for High Temperature Applications

a. High temperature insulation shall be used where connected to heat-generating apparatus, where the ambient temperature can exceed 257ºF, or where Teflon is specified as a requirement. The insulation shall be rated at 1,000 VAC and VDC in the case of wires carrying a nominal voltage greater than 150 VAC or VDC, and rated at 600 VAC and VDC in the case of wires carrying a nominal voltage equal to or less than 150 VAC or VDC. The insulation shall have a continuous temperature rating of 257°C or above and be in accordance with the following requirements:

i. For wire sizes AWG No. 16 and larger, abrasion resistant Teflon (Polytetrafluorethylene - PTFE) meeting MIL-W-22759/6B or 10B, as appropriate for the voltage level used, or silicone rubber meeting AAR Standard RP-587C.

ii. For wire sizes AWG No. 18 and smaller, abrasion resistant Teflon (PTFE) meeting MIL-W-22759/6B or 10B, as appropriate. When used for interconnecting pieces of apparatus, this type wire shall be in bundles with a protective covering of high temperature rated, low smoke generating insulation.

b. The Contractor may propose other insulated wire specifications for approval in a specific high temperature application, specifying the design ambient temperature, routing, RMS ampere value, worst-case ampere value, worst-case temperature rise, stranding, and insulation material specification.

c. No high temperature insulated wire shall be used in conduit or raceways without specific approval. The Contractor shall submit all applications of high temperature wire insulation for approval.

5. Wire Insulation within Equipment

    a. Insulation on wiring within replaceable modular units, electronic apparatus such as cards and card racks, and other equipment, as approved, shall be Tefzel (Ethylenetetrafluoroethylene - ETFE) per ASTM D3159 and insulation construction per Military Specification MIL-W-22759/16 (AS), irradiated cross-linked polyolefin per **Part 21.20C.2**, or Teflon (Polytetrafluorethylene - PTFE) type EE per Military Specification MIL-W-16878/5.

6. Wire Insulation at Crowded Locations

    a. Wire for connections to the control console, or in any other locations where there are equally crowded concentrations of low voltage control wiring, may be insulated with Tefzel (ETFE) per ASTM D3159 and insulation construction per Military Specification MIL-W-22759/16 (AS), except the wall thickness shall be 0.025 inches. When used for this application, these type wires shall be bundled with a protective covering of irradiated cross-linked modified polyolefin or similar, approved, high temperature rated, low smoke generating insulation.

D. Multi-Conductor Cables

1. General

    a. Multi-conductor cables, where approved, shall be constructed using wiring as described in **Part 21.20E**. For high temperature applications, the cable shall conform to MIL-C-27072, with Type V connectors, Style 4 sheaths, Class D jackets, if needed, and shields, if needed. All conductors in multi-conductor cables shall be color coded or otherwise permanently identified as approved. Materials used in the construction of multi-conductor cables shall meet the requirements below. In applications where current is not a factor in wire size selection, such as LED indicator lights or status displays, AWG No. 16 may be used between repeater devices and displays. For multi-conductor cables carrying low-voltage, high-speed, serial data, exceptions to the wiring requirements may be submitted for approval, based upon availability of wire to meet the application requirements.

2. Fillers

    a. Where required to obtain a circular cross-section, fillers shall be made of non-hygroscopic materials compatible with the wire insulation and jacket, and shall be of the same or of a higher temperature rating than the wire insulation.

3. Tape

    a. A binder tape shall be employed over the assembly of conductors in multi-conductor cables if needed to assist in cable manufacture, or as required to permit the cable to function as intended in its application. The binder tape material shall be non-hygroscopic and shall be of the same (or better) temperature class as the wire insulation, and shall be of a compatible material.

4. Shield

    a. The shield, if required, shall consist of either tin plated copper braid (concentrically

served) or aluminum/polyester tape with a drain wire, as is appropriate for the application. Tape shields shall be permitted for fixed installations only. The shields shall have the following minimum properties:

i. Copper shield shall be made of either tinned, coated copper strands which conform to ASTM B33, or silver-coated copper strands which conform to ASTM B298, as is appropriate for the wire insulation. Shield coverage shall not be less than 85 percent. Shield strand size and application shall be as recommended by the cable manufacturer for the particular application, but shall not be smaller than AWG No. 38.

ii. Aluminum/polyester tape shields shall consist of a helical wrap of aluminum/polyester tape with a nominal thickness of 0.0004 inch aluminum on a backing of 0.001 inch polyester. The tape shall have a minimum overlap of 10 percent of the tape width to ensure complete coverage. In contact with the aluminum side of the shielding tape shall be a AWG No. 22 7/30 tinned copper drain wire conforming to ASTM B33 and B174.

5. Jackets

a. The overall jacket of multi-conductor cables shall be of flame retardant, irradiated, cross-linked, modified polyolefin; Tefzel (ETFE); or Teflon (PTFE) to be fully compatible with the wire insulation and application as approved. The coupler cable shall have a jacket of low temperature arctic grade neoprene per MIL-C-13777, with a wall thickness suitable for 600 VAC. The jacket shall be extruded and vulcanized over the cabled conductors, and shall be centered, with a smooth appearance without objectionable roughness or irregularities, consistent with good industry practice. The nominal jacket thickness for polyolefin, Teflon, Tefzel and Neoprene shall be that shown below, with the minimum wall not less than 80 percent nominal value.

Figure 21-8: Multi-Conductor Cable Nominal Jacket Thickness Requirements

Cable Diameter Under Jacket	Modified Polyolefin	Teflon or Tefzel	Neoprene
0.000-0.250	0.045	0.010	0.072
0.251-0.500	0.045	0.015	0.087
0.501-0.750	0.060	0.021	0.1
0.751-1.000	0.080	0.021	0.1
1.000-1.500	0.080	0.025	0.115
1.501-2.000	0.11	-	0.135
2.001-2.500	0.13	-	0.152
2.501-3.000	0.14	-	0.195

E. Wire Wrap

1. Wire wrap connections may be used in selected electronic applications, where approved. Where used, the following standards, as a minimum, shall be followed:

a. Only soft or annealed oxygen-free solid copper conductor shall be used.

b. Wire size shall be AWG No. 28.

c. A silver conductor coating, with a minimum coating thickness of 40 micro-inches, shall be applied to the wire.

d. Wire shall have "MIL-ENE" insulation, or approved equal manufactured to MIL-W-81822/1A. The insulation shall have a minimum 300 VAC/VDC voltage rating and shall allow a 275°F maximum conductor temperature.

2. Wrapping shall be “modified” wrap, nominal 7-1/2 turns, including 1-1/2 turns for strain-relief.

F. Insulation Smoke Test

1. Scope

a. This test method describes the equipment and the procedure for preparing insulated wire samples from which the specific optical density (Ds) of smoke generated can be determined in the Aminco-NBS Smoke Chamber. This method is used for wire sizes up to and including AWG No. 12. For wire sizes above AWG No. 12, the standard procedure outlined in ASTM E662 shall be used. Equipment calibration, standardization, and operation are to be in accordance with ASTM E662, Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials. The performance criteria shall be Ds (4.0) </= 200 (flaming) and Ds </= 75 (non-flaming).

2. Apparatus

a. Aminco - NBS Smoke Chamber and Recorder.

b. Aminco 6 tube, 90 degree burner assembly for flaming mode testing. Burners are all directed in one plane at the sample.

c. Notchless wire frame (Aminco AWG No. 20 wire frame with notches machined off).

d. Aminco troughless wire specimen holder assembly.

e. Air oven.

f. Humidification chamber.

g. Heavy duty aluminum foil 0.001 ±0.0005 inch.

h. Razor blade.

i. Tape measure.

3. Procedure

a. Determine the length of insulated wire required for testing. The individual sample length shall be calculated to produce a sample area of 35 square inches.

i. Calculate the sample length as follows:

$$1 = \frac{35}{3.1416 \times d}$$

where: l = sample length
d = diameter of insulated wire (inches)

ii. Cut and identify a minimum of three samples of the required length.

iii. Condition samples prior to testing by pre-drying in an air oven for 24 hours at 140°F ±5°F followed by humidification at 73°F ±5°F, and a relative humidity of 50 percent ±5 percent, for a minimum of 24 hours.

iv. After conditioning, wind a sample uniformly around the wire frame so that the frame opening is uniformly covered.

v. Cover the wire-wrapped frame with aluminum foil across the back, along the edges, and over the front surface's periphery with a single sheet of aluminum foil, with the dull side in contact with the wire.

vi. Place the foil-wrapped wire in a trough less sample holder such that the wire is vertically oriented. Insert millboard backing, spring, and retaining clip.

vii. Carefully trim the aluminum foil from the front opening of the sample holder.

viii. Adjust wire turns, if necessary, to assure that the sample holder opening is uniformly covered.

ix. Perform smoke testing in accordance with ASTM E662, noting any unusual behavior that occurs during the test; for example, self-ignition of the sample in the non-flaming test mode or any extinguishment of a burner triplet during the test.

b. Report the sample orientation, test conditions, results, and observations made during the test.

21.21 WIRING, TERMINALS, AND CONNECTIONS

A. General

1. All locomotive wiring shall be in conformance with the AAR Manual of Standards, Section F S-538, "Wiring Practice and Rolling Stock Standard", and APTA RP-E-002-98, “Recommended Practice for Wiring of Passenger Equipment,” except where otherwise specified, and except that all wire shall be as required in this Specification. Circuit protection shall be in conformance with Chapter 2 of NFPA 70, Article 240.

2. All equipment enclosures and junction boxes, except primary power circuits, shall be fitted with terminal boards or connectors. Primary power circuits shall be fitted with compression terminals and knuckle joint connectors as described herein.

3. All wire passages into equipment enclosures, junction boxes and/or equipment boxes shall be protected and support to prevent any damage from chaffing and rubbing on surfaces.

4. The Contractor shall submit the proposed design and product line for all connections for approval. Terminal boards with M4 or Number 6 or smaller screws and quick-disconnect terminals, other than those stated herein, shall only be permitted with approval.

B. Wire Handling

1. All wiring shall be performed by qualified, experienced wiring personnel using appropriate tools for stripping insulation, cutting, tinning, soldering, harness making, attaching terminals, and other wire fabrication tasks. All wiring tools and equipment shall be used as recommended by the tool and equipment manufacturer.

2. Wire shall be protected from damage during all phases of equipment manufacture. Wire shall not be walked on, dragged across sharp or abrasive objects, kinked or twisted, or otherwise mishandled. The ends of wire shall not be permitted to lay on wet floors or other damp areas where moisture may be absorbed into the conductors.

3. When removing insulation, wire strands shall not be nicked or broken in excess of the requirements of FAA Specification No. AC 43.13-1A, Section 449, "Stripping Insulation".

4. Additionally, the following criteria apply:

Figure 21-9: Maximum Number of nicked Strands by Wire Size

Wire Size	**Maximum Number of Nicked Strands***
Wires smaller than No. 10	None
No. 10 through 1/0	7.4 percent
Above 1/0 through 1600/24	4.4 percent
Above 1600/24	graduated scale

5. Definitions:

   a. A cutoff strand shall count as two nicked strands.

   b. A nick is defined as 25 percent or more of the strand area damaged, or cut more than 33 percent of its diameter.

6. Longitudinal scratches in a copper strand are not considered cause for rejection.

7. Wiring Layout and Installation

   a. Wire Harness

      i. The layout of wiring, for both locomotive and equipment, shall be designed in advance of its installation and in cooperation with the suppliers of the related equipment. Wiring shall be pre-fabricated into standard harnesses, wrapped or

tied with spiral wrap or tie wraps. Harnesses shall be installed with identical arrangement and location in each locomotive having similar equipment. Separate harnesses shall be provided for major circuit groups or types, or as required for specified circuit separation. All circuits and branches shall be separated by means of terminal boards to isolate portions from others for troubleshooting and searching for undesired grounds. All circuits subject to periodic high potential tests shall be so arranged that they can be conveniently set up for the tests.

ii. Alternative methods for fabricating and installing wiring, which are standard Contractor practice, shall be considered for approval by the Authority.

iii. Harnessed wires shall not be installed in conduit. Wires from different conduits or other openings shall not be harnessed together with wires running within the box or entering the box through another entrance point. Each harness or group of wires between equipment enclosures shall contain a minimum of 10 percent spares, but no less than one spare for each wire size whichever is greater.

8. Circuit Separation

a. Circuits shall be physically separated to reduce the possibility of unsafe conditions, interference, or equipment damage.

b. The following major circuit groups shall not be harnessed or bundled together, shall not run in the same conduit, and shall be physically separated and secured in enclosures, wire ducts, junction boxes, or other wire routing devices:

i. High voltage circuits,

ii. AC circuits,

iii. Communication circuits,

iv. Battery voltage level circuits,

v. Semiconductor gating voltage level circuits, and

vi. Conductors carrying in excess of 100 Amperes.

c. Wires which are connected in circuits with potentials differing by 50 Volts or more shall be separated by a physical barrier. The wires shall not be cabled together and shall not be placed in the same conduit, junction box, or enclosure. Where a raceway, duct, junction box or enclosure is divided into two or more distinct areas by metallic partitions, each area may be considered separately in the application of this rule.

d. Where it is impossible to avoid having wires at different voltages in the same equipment enclosure, the wires shall be physically separated, bundled, and secured separately such that contact between wiring is not possible. All wiring within an enclosure shall be insulated for the highest voltage in the enclosure, unless approved otherwise. All wiring connected to a piece of apparatus shall be insulated for the

highest voltage connected. Wiring connected to transient-generating apparatus, such as unsuppressed contactor coils, shall not be run adjacent to wiring carrying signals to, from, or between semiconductor circuits, logic circuits, vital no-motion circuits, or communication circuits. In cases in which adequate physical separation is impossible, shielded wire shall be used for all conductors involved.

9. Wire and Cable Runs

   a. Wire runs shall be continuous and unbroken between connection points, shall be supported at no greater than 2 foot spacing, and be protected at each support point against mechanical crushing and abrasion. A watertight bushing and drip loop shall be provided on all exposed cable entries. All cable bundles and wires shall be routed a minimum of 1 inch above the bottom of equipment enclosures.

   b. All undercar wiring smaller than AWG No. 6 shall be run in closed wire ducts, conduits, or open wire mesh wireways in an approved manner. Wire and cable shall be secured within ducts or open wireways, including each entrance and exit point, to prevent chafing movement. Wire ducts and conduits shall be of waterproof construction. Permanently retained watertight strain relief bushings, with insulated throat liners, of an approved design, shall be used at locations where wires, cables or harnesses enter or exit conduit, ducts, apparatus and equipment enclosures. In addition, strain relief bushings on equipment enclosures shall include a permanently retained O-ring type seal.

   c. Lead wires to resiliently-mounted electrical apparatus shall be carried in conduit to a point as close to the apparatus as possible. The length of the leads between the end of the conduit and each piece of apparatus shall be as approved. Short runs of cables or harnesses entering or leaving conduit and apparatus shall have an approved guard mounted to the locomotive body to protect the wires from mechanical damage. Lead wires to solidly-mounted, electrical apparatus and equipment enclosures shall run in conduit connected to the apparatus or enclosure.

   d. All wiring routed from enclosed areas of the carbody to areas exposed to the elements (including underframe and roof areas) or between interior levels shall be run in ducts or conduit. Wiring, even if enclosed in loom, must not be run through partitions without suitable bushings being provided at such points of passage.

   e. Cables shall be laid in place with sufficient slack at the bends so that cables shall clear the inside bend surface of the wireway/wire duct.

   f. All wire and cable shall be free of kinks, insulation damage, insulation abrasions, and nicked strands. Wire installation shall not be subject to accumulations of water, oil, or other foreign matter.

   g. Wires or cables shall not pass through or over the battery compartment and shall not pass over heat generating equipment such as acceleration and braking resistors, even if the wires or cables are in conduit.

   h. Exposed harnesses, short cable runs or harness entering or leaving exposed raceways shall have approved, fire-resistant flexible dielectric sleeving over the raceway edges and grommet-type insulation of any penetration holes. Wiring shall be retained to

the sleeving with tie-wraps.

i. Cable Cleating and Support

i. All cable and wiring exiting wireways/wire ducts, or that which is not installed in conduit, shall be cleated using split-block cleats of molded neoprene rubber, fabricated plastic or fiberglass with neoprene cushion inserts. In no case shall nylon wire ties be used as the means of supporting the weight of wire bundles and cables. Cables shall be cleated and bushed when passing through bulkheads and structural members. The cushioning material shall be non-conductive, fire retardant insulating material with a durometer of 50 to 60 meeting the requirements of Part 21.09. Each cleat shall have a stiffener of at least 10 gage material on the side away from the mounting bracket which shall act to spread the bolt clamping force over the entire length of the cleat. Bolts shall have lock nuts. The Contractor shall minimize the quantity of different configuration cable cleats.

ii. AWG No. 6 or larger insulated wire may be cleated in place without conduit, duct or open wireway. However, in the areas over the truck, in the wheel wash and not protected by underfloor-mounted equipment, the wire shall be mechanically protected by an open mesh, expanded metal or other type of approved guard. The guard may be attached to the bottom of each cleat with the cleat clamping bolts or other approved arrangement.

iii. Cleats shall be designed to grip each cable individually and firmly, but without causing any damage to cable insulation, including cold flow of the insulation. Each cable in the cleat shall have its own cutout sized to the correct wire diameter. Cleated cables shall be routed and supported such that they cannot, under any combination of forces and locomotive movement, touch each other or any other part of the locomotive, except the cleat cushioning material.

iv. Wire and cable runs shall be continuous and unbroken between terminations and shall be supported at not greater than 24 inch intervals in ducts, open wireways or when cleated. The wire shall be protected at each support point against mechanical crushing and abrasion.

v. Wire splices shall not be permitted, except with express written approval and in accordance with the wire splicing requirements of **Part 21.21L**.

vi. Concealed wires, such as within conduits and wire ducts, shall be such that wires may be replaced or added to without the removal of other than access panels. It shall not be necessary to disconnect or disassemble conduit to accomplish this task.

vii. Wiring run in loom shall not be carried over a potential chafing hazard. Wires entering any removable box shall be harnessed and secured to facilitate removal of the box.

viii. All wires and cables shall be fully protected against any contact with any surface other than that designed specifically to support or protect them. This

applies to all current carrying wires, cables or buses on the vehicle.

j. Wire Securement and Termination

i. All wiring shall be secured and protected against movement, chafing, and any contact with conductive, sharp, or abrasive objects including the inside surfaces of wire runs.

ii. All wiring shall be located and secured such that normal equipment motions, maintenance access, heat sources, and the environment do not damage or reduce the life of the wiring.

iii. Junction boxes, with terminal boards, shall be used, as required, for wire terminations. Harness connections to the boxes, as well as internal wiring to terminal boards, shall be as specified in **Part 21.21B**. Exterior junction boxes shall be weather tight.

iv. In cases where it is necessary to anchor wires or cables to metallic parts of the locomotive, cleats or approved stainless steel bottle clamps shall be used. Wires and cables shall not be allowed to chafe or rub against any part of the locomotive or each other under any circumstances.

v. Wire and cable dress shall allow for sufficient slack at equipment terminals to provide for movements induced by shock and vibration, equipment shifting, alignment, cover removal and component replacement. Sufficient lengths shall be provided at points of termination for additional reterminations without applying tension to the wire and without splicing the wire, as follows:

(a). AWG No. 10 and smaller - Three reterminations

(b). AWG No. 8 and larger - Two reterminations

vi. A drip loop shall be provided on all exposed wires and cables to prevent fluid runoff into connected equipment.

vii. Spare wires, which are part of a wire harness, shall be bundled separately inside of the equipment box to which the harness is being terminated. Spare wires shall have enough length to reach any location within the box, including sufficient slack for the required number of reterminations. The spare wire "break-out" bundle may be tie-wrapped to the main harness, but shall be easily removed from the main harness without disassembling it. The ends of the spare wires shall be insulated against inadvertent contact with any nearby conductive surfaces or terminals. Each wire routing shall have a minimum of 10% spare wire runs.

viii. Wire tying devices shall be of such material and construction that they shall adequately retain the wires for the life of the wiring and shall be resistant to ozone and ultraviolet light. Wire and cable ties shall be trimmed and located to eliminate any hazard to personnel from sharp edges. Wire tying devices shall be snug, but shall not be so tight as to cause indentation and cold flow damage to the insulation. Wire tying devices shall be mechanically fastened to a permanent structure. Adhesive-installed mounting bases shall not be used

for ties or for cable support.

ix. All wire bundles and cables within an enclosure shall be supported by the use of tape rails, shall be spaced away from the equipment box structure, metal edges, bolt heads, and other interference points, and shall have electrical clearance from the covers, regardless of the insulation properties of covers. Wire bundles shall be located above or alongside the apparatus rather than at the bottom of the box wherever possible. In all cases, wire shall be a minimum of 1 inch above the bottom of the box, unless otherwise approved by the Authority. Wire entry into control or junction boxes shall not be permitted through the bottom of the box.

x. Truck wiring shall be designed to ensure sufficient slack, and shall be provided with clamp supports and abrasion protection. T-splices shall not be permitted.

xi. All jumpers, jumper heads, and jumper receptacles shall be sealed in an approved manner to prevent the entry of water at any operational speed of the locomotive.

xii. Any wiring needed to calibrate and test locomotive functions shall be a part of the permanent locomotive wiring to enable the Authority to conveniently maintain the equipment. This wiring shall terminate in approved connectors in the respective control groups and cabinets.

xiii. The Authority desires to have wiring and cabling readily accessible for inspection and maintenance. Extensive wiring and cabling in the vehicle interior is contrary to accessibility, even though access panels, false floors, and other portals may be provided. To control this, the Contractor shall submit a complete wiring plan for approval.

xiv. Wire and cables that are subject to high currents in fault conditions or normal operation must be secured against secondary damage due to the high magnetic forces that are developed. Propulsion inverter circuits are a typical example. This includes damage to bus bars or devices to which the cables terminate.

10. Circuit Shielding

a. Wire shields used in trainline circuits shall be continuous up to the locomotive's electrical coupler contacts, including contacts of the jumper cable connector at the intermediate couplers. The wire shields shall be connected through all applicable connectors and junction boxes. Circuits shall be categorized. Shields contained in one circuit category shall not be interconnected with shields contained in another category. Shields used to protect against interference shall not carry signal current.

b. Shields on low-level signal wires shall not be interconnected with shields on high-level signal wires in the same category. Each group of shields (other than at the electric couplers, including the jumper cable connectors at the intermediate coupler) shall be carried through on a connector pin or pins, or on terminal strips which shall be in the immediate proximity of the categorized group of circuits. Loops due to interconnections of shields shall not be permitted.

c. Coaxial cables used as constant impedance transmission lines shall be terminated as dictated by the circuit termination design and shall not be considered to be shielded conductors. Triaxial cables may be used as coaxial impedance transmission lines with the outer conductor employed as an RF shield.

d. The following three items shall be considered as guidelines and are not absolute requirements:

i. Shields used to suppress electromagnetic interference (EMI) at all frequencies shall be terminated only at the low potential side of the interference circuit, at the termination which exhibits maximum susceptibility.

ii. Shields used to protect against the effect of, or to exclude, EMI at frequencies below 150 kHz, shall be terminated either to the low potential side or at the balance point of the protected circuit at the termination which exhibits maximum susceptibility.

iii. Cables requiring both audio frequency (AF) and radio frequency (RF) shields shall be electrically isolated from each other. The resistance between these circuits shall be at least 500 megohms when 500 VDC is applied. Double shielding shall be required on circuits that are both AF-susceptible and RF-susceptible.

C. Marking and Designation

1. The Contractor shall devise, and submit for approval, a wire and terminal marking and designation system that shall coordinate all electrical circuits in the locomotive into a unified system.

2. The system shall identify all wiring, including circuit return wiring, and terminals according to their respective circuit function(s) and shall accurately correlate these designations with the locomotive schematic diagrams. Each circuit shall be individually designated from point to point. Common designations for return circuits are not permitted.

3. Each wire and cable shall have printed on the outer surface, the manufacturer's identification, conductor size, temperature rating, and voltage rating. For wire size 1/0 and larger, stranding shall be given in addition to the other parameters.

4. Except for spares, TFE Teflon insulated wires and wires entirely within an equipment enclosure, each wire #8 AWG and smaller shall be permanently and legibly marked along its entire length. Wires larger than #8 AWG and TFE Teflon insulated wires may have wire markers applied at each end of the wire. Blank spaces between markings shall measure approximately 1.5 inches. Spare wires and wiring entirely within an equipment enclosure may have a single wire marker at each end, subject to approval by the Authority in lieu of continuous marking. Wires shall be marked with their alpha-numeric circuit designation. A circuit designation shall change only when it goes through an active or passive component such as a relay coil or relay contact, fuse or circuit breakers, lamp, motor or resistor. A circuit designation shall remain unchanged when it goes through a terminal strip or junction box stud regardless of how many wires of that circuit are common to that point. There shall be no duplication of wire codes in unrelated

circuits throughout the locomotive. Where there are more than one of a particular assembly per locomotive, each assembly shall be wired identically to the other(s) and wire marking of harnesses shall be identical in each assembly.

5. For pre-manufactured multi-conductor cables and for cases where individual circuit identification markers may be approved the following requirements apply:

6. All wires and terminals shall be clearly identified. Wires attached to terminal studs shall also have a marker indicating the terminal stud to which it is attached.

7. Identification of wires and terminals shall be by white or yellow permanent markers, with black printing or by continuous wire marking printed on the wire. All wires shall be marked 6 inches from of the end of the wire (both ends) and every 24 inches over the remainder of the wire. Wire markers shall be stamped in two places, approximately 180 degrees apart, to facilitate readability of the marking. Wires in multiple-conductor cables shall be color-coded.

8. Wire markers shall meet the adherence and solvent resistance requirements as specified by MIL-M-81531 Sections 3.4.2 and 3.4.3, latest revision, and shall withstand all combinations of ambient and equipment temperatures. Hand printing is prohibited.

9. For cable identification, the contractor shall submit the system selected for review by the Authority.

D. Pulling Compound

1. Pulling compound shall be non-conductive, non-hygroscopic, non-odorous, shall not support bacterial activity, and shall not attract vermin.

E. Solder

1. Solder shall be in accordance with ASTM B32, Grade Sn60. A flux of non-corrosive type shall be applied immediately before soldering.

F. Tape

1. Electrical tape shall be in accordance with AAR Standard S-540 of Section F of the AAR Manual Standards and Recommended Practices, or equivalent approved railway practice. Electrical tape shall meet or exceed the voltage rating of wire where the tape is applied.

G. Terminal Boards & Terminal Points

1. Electrical terminal points and terminal boards shall have brass studs and connections, each of which shall be locked using a single brass nut with brass flat washer and a plated spring-type lock washer. Studs, nuts, and washers may also be made of corrosion-resistant, plated steel, where approved. Each board or connector shall have the necessary number of terminations plus a minimum of 10 percent spares, but not less than one spare unless approved. Binding head, screw type terminal boards shall be permitted only where approved. Terminal boards of this type shall be in accordance with Military Specification MIL-T-55164A.

2. Threaded studs shall have a minimum of 2-1/2 threads exposed beyond the final nuts.

Adequate space shall be provided to permit connecting wire terminals with standard tools. All terminals shall be properly torqued to assure sound connections. Spacers shall not be used.

3. A maximum of two terminals shall be connected to any one binding screw. A maximum of four terminals shall be connected to any one threaded stud, provided that there is no interference between terminal barrels. On terminal boards, the wiring shall be arranged so that no more than two terminals are connected to a stud, from each side of the terminal boards.

4. Molded case, modular terminal blocks which utilize a spring clamp to hold the wire may be used for low voltage circuits. Each terminal block shall be properly identified with a permanent marking and each assembly shall be secured to the mounting (DIN) rail by end clamps which incorporate metallic hardware. All wires AWG 12 and smaller shall receive a ferrule. Plug-in style (split) terminal blocks shall only be permitted if, as part of the design, these plugs shall be used as a connector when performing maintenance, testing or replacement of a Line Replaceable Unit. All molded case, modular terminal blocks are subject to review and approval by the Authority.

5. Jumpers between terminal board points shall be brass or plated steel. Wire jumpers between adjacent terminals of terminal boards shall not be permitted.

6. An approved permanent marking strip on each terminal board shall be provided and attached adjacent to the wire junction point to identify the wires attached thereto and/or the wires connected to terminal boards shall have the terminal point location printed on the wire.

H. Wire Terminations

1. Terminals and connections used throughout the locomotive shall be the mechanical, solderless, crimp type made by AMP Incorporated or other approved manufacturer with a comprehensive line of terminals, connector pins, and application tools available. All terminals for the same wire size shall be crimped with the same model tool. The Contractor shall minimize the total number of crimping tool types needed for all crimp connections. Terminals fitting wire sizes AWG No. 10-22 shall require no more than three tool models to provide certified crimp connections. The Contractor shall submit the proposed product line for approval. Terminals to be approved shall be tested to Military Specification MIL-T-16366F for temperature rise, voltage drop, vibration, current overload, and corrosion. Test results shall be submitted for approval on a by part number basis.

2. Terminals and connections shall be attached to the wiring with proper crimping tools and dies as recommended by the manufacturer. The terminals used on conductors of size AWG No. 10 or smaller shall be of the type which securely grips and holds the insulation of the conductor, unless approved. Terminals shall be ring lugs in accordance with Military Standard MS-25036.

3. For components that do not accept ring tongue terminals, appropriate alternate terminations such as ferrules, locking forks or quick disconnects may be used subject to approval by the Authority. Corrosion protection shall be provided for all base materials.

4. Conductors subject to motion relative to the terminal shall be protected by suitable means to prevent breakage of the conductor at or near the terminal. Sufficient slack shall be provided in all wires and cables to prevent breaking or pulling out of bushings and terminals. A maximum of one wire shall be crimped in any one terminal.

5. Wherever several wires are connected to terminals of a terminal strip on a device which is removable from the locomotive for maintenance, the wires shall be terminated, with double ring terminations which shall be screwed to an insulating fanning strip which shall serve to keep the terminations in the correct relative locations while removed from the device, unless otherwise approved by the Authority.

I. Power Cable Terminations

1. Power cables shall be terminated with an approved compression terminal. Sufficient cable slack shall be provided to preclude breaking or pull-out from bushings or terminals and to allow two terminal changes. Cable conductors shall be clean prior to installation of terminals.

2. Compression terminals shall be applied using tools and procedures recommended by the terminal manufacturer for that purpose. Swaging tools shall be of a type that ensures complete swaging in every case.

J. Cable Connectors

1. All cable connector applications shall be approved.

2. All cable connectors shall conform to MIL-C-5015 or an equivalent standard as approved. They shall employ removable crimp contacts of the correct size for the wire being terminated. Except as noted below, the connector contact area shall be plated with a minimum of 0.000030 inch of gold over a minimum of 0.000050 inch of low stress nickel. For high current applications, the connector contact area shall be plated with a minimum of 0.00010 inch of silver. Adjacent connectors shall either use different inserts or different insert orientations to prevent erroneous connections. The receptacle half of all cable connectors shall be rigidly mounted.

3. All cable connectors used in exterior locations shall be of the environmental watertight variety. Cable connectors shall be equipped with sealing gaskets on the front mating surface and on the back where the cable enters. The cable jacket shall be held by a clamp within the connector body. Unused connector pin positions shall be sealed with either connector contacts or plastic sealing plugs designed for that purpose.

4. Plastic bodied connectors shall not be used in exterior locations. Quarter turn, bayonet-lock, quick-disconnect type connectors shall not be used on trainline jumper cables.

5. Except as specified above all cable connectors in exterior locations, shall be quarter turn, bayonet-lock, quick disconnect type CIR connectors as made by Litton-Veam SPA, or approved equal. Quarter turn, bayonet-lock connectors shall conform to all provisions in MIL-C-5015, or an approved standard, except for the screw coupling requirement.

6. Connectors in high vibration or high motion areas, such as speed sensors and trainline jumpers, shall have the wire connections soldered and potted and shall have a watertight jacket molded over the cable and connector to form a unitized assembly. Trainline jumper

connectors used shall be as made by Pyle-National, or approved equal. The Contractor shall conduct an approved vibration test on these unitized assemblies.

7. Non-metallic body, non-environmentally sealed connectors are limited for use on non-vital, interior applications, such as lighting and speaker connections. These connectors must be threaded or include a positive locking mechanism. All such connectors must include a suitable means of strain relief for the wires. If a spring-clamp is used to terminate the wire within the connector body, a properly sized ferrule must be applied to the wire. The receptacle half of each connector assembly shall be rigidly mounted. Proposed connectors shall have a minimum of 2 years of successful service in similar applications and are subject to approval by the Authority.

K. Grounding Return Connections

1. Grounding

a. Grounding connections to the locomotive body and equipment shall be made through copper pads of an adequate area, silver soldered or brazed. Alternative ground pad material may be permitted in certain cases as approved by the Authority. Transition (base) plates if used, shall be made from the same alloy group as the respective locomotive body and piece of equipment. The base plate shall be welded to the locomotive body or equipment. Grounding connections shall not be made to aluminum alloy members. All ground pads shall be visible and accessible for inspection and troubleshooting. The ground connections shall be attached by a bolt, washer, and nut designed for the purpose. An anti-corrosive grease shall be applied over the connection.

b. All equipment enclosures and shock-mounted equipment, except the operator cab lights, shall be grounded with flexible, grounding leads bolted between a locomotive body grounding pad and the equipment's grounding pad. Braided, strap-type leads shall be used where there is relative motion between the two items being connected. The ground strap termination method shall apply uniform pressure to the conductive surface.

c. The Contractor shall design a complete grounding scheme, which shall indicate the means by which it is proposed to prevent currents from passing through journal and truck-center bearings. Refer to other sections of this Specification for ground brush and related requirements. Low voltage and high voltage circuits shall not be grounded to the same ground.

2. Bonding

a. All grounding and bonding jumpers and straps shall be sized to handle fault current and lightning discharge current, for which the voltage drop shall not exceed 25 Volts. The bonding method employed shall not produce a DC resistance in excess of 0.0025 Ohms, or more than 0.025 Ohms at 150 kHz for any applied AC voltage. Grounding and bonding jumpers, and brazed shunt straps shall be "extra-flexible".

L. Wire Splicing

1. Splicing of conductors shall be avoided and shall be permitted only with approval on a

case-by-case basis. Splicing of conductors in conduit shall not be permitted. In the event a splice is approved, it shall be in a junction box and the spliced joint shall be mechanically as strong and have the same conductivity as any other part of the conductor. The splice shall be an insulated permanent crimp splice in accordance with Military Specification MIL-T-7928G, Type II, Class I, and shall be installed with the crimping tool and die of the splice manufacturer. All splices shall be insulated with a self-sealing, weather-tight, seamless shrink tubing. The outside diameter of the spliced portion of the cable after the insulation is applied shall not exceed the outside diameter of the un-spliced portion by more than 40 percent. Splices shall be identified in the integrated schematic

21.22 WIREWAYS, CONDUIT, JUNCTION BOXES, AND FITTINGS

A. General

1. The conduit, conduit fittings, and junction boxes for locomotive wiring shall be as manufactured by the Contractor or by a supplier of a comprehensive line of parts. The Contractor shall submit the proposed product line for approval. All conduit fittings and junction boxes shall be provided with gasketed covers. All conduits and their connections to electrical equipment shall be installed to make a continuous ground.

B. Conduit Types

1. All conduit and conduit couplings shall be of an ANSI-approved type. All conduit shall be standard weight, galvanized steel with threaded fittings. All conduit ends shall be deburred inside and out to remove sharp edges and all pieces shall be blown out with compressed air and cleaned before installation to remove filings and other foreign material.

2. Steel conduit shall be mild steel in standard lengths with threaded ends and hot-dipped zinc-coated exterior and interior surfaces. It shall be free of burrs and projections, circular in cross-section, of uniform wall thickness and shall conform to the requirements of ANSI Standard C-80.1. The threads per inch and length of threading shall conform to ANSI Standard B-2.1 on pipe threads.

3. Steel fittings shall be used to assemble steel conduit. Elbows, nipples, and couplings shall be made of the same grade of steel as that employed in the conduit. All fittings shall be treated, coated, and threaded according to the requirements for zinc-coated, rigid steel conduit and shall conform to UL 6.

4. Thin-walled, Electrical Metallic Tubing (EMT) or aluminum conduit shall be permitted for interior use only. All applications of such conduits shall utilize compression-style connectors and couplings.

5. Flexible conduit, if used, shall be watertight and interlocking aluminum such as Anaconda sealtite or steel strip-protected, with an approved rust resistive coating. Flexible covering on conduit shall not contain polyurethane or PVC vinyl.

6. Liquid tight flexible nonmetallic conduit, if required for special applications, may be used with the Authority's approval. Liquid tight flexible nonmetallic conduit shall not be used where subject to physical damage or in lengths longer than 6 feet.

7. Conduit shall be color-coded: red for those carrying circuits above 100 Volts and yellow

for under 100 Volts.

C. Junction Boxes

1. All new exterior junction boxes shall be fabricated of minimum 14 gauge steel or aluminum. All exterior junction boxes shall be weatherproof and shall be connected in such a way that drainage from equipment groups shall not pass through conduit into the junction boxes. Interiors of all junction boxes shall be primed and then protected with a white, insulating coating as specified in Part 21.16D.

D. Covers

1. All new junction box covers shall be dust proof, retained by compressive spring-type latches, or captive screws as approved on a location-by-location basis. All fasteners used in junction boxes shall be stainless steel. All covers shall be designed to accept or mate with a bulb-type clamp-on seal.

E. Wireways

1. Wireways shall be permitted in approved exterior and ceiling locations only. They shall not be permitted in the locomotive body sidewall area. Only conduit shall be permitted in the locomotive body.

2. All wireways shall be of rigid, stainless steel construction. Wireways shall be color-coded; red for those carrying circuits above 100 Volts and yellow for fewer than 100 Volts. The trays shall be adequately supported throughout their entire length in an approved manner. The trays shall be completely de-burred, leaving absolutely no sharp edges, before installation on the vehicles. Grommet clamps shall be provided at all locations where cables or wires enter or leave the wireways. Under no circumstances shall leads be draped over the edge of the wireways, with or without wireway edge protection. Heads of screws or bolts inside the raceways shall be flush with the metal surface. Metal wireways, elbows, couplings and similar fittings shall be flush with the metal surface. Points of screws or fasteners shall not be directed toward the interior of wireways. Removable wireway covers shall be secured with captive fasteners.

3. Wireways shall be designed to prohibit the collection of dirt and debris, and shall be perforated, without compromising their requisite strength, to permit ventilation and drainage. They shall preclude water entrapment.

F. Conduit Interface

1. The open ends of conduit shall be provided with strain relief type fittings with extended rubber bushings, bell-mouth fittings, or insulated throat box connections as approved. All conduit entries into removable equipment boxes shall be secured by means of a bolt-on watertight access panel.

G. Size and Fill

1. Conductor area, including wire, insulation, and jacket shall not exceed 40 percent of the interior cross-sectional area of the conduit unless approved by the authority, but in no case should exceed 60 percent. Where conduit having a length not exceeding 24 inches without bends of more than 15 degrees is used between enclosures, a maximum fill of

60 percent shall be permitted.

2. Wireways shall not contain more than 30 current-carrying (i.e., power source as opposed to signaling) conductors at any cross-section. Conductor area, including wire, insulation, and jacket shall not exceed 40 percent of the interior cross-sectional area of the wireway unless approved by the authority, but in no case should exceed 60 percent.

H. Installation

1. Conduit

a. A run of conduit between junction boxes and/or pulling outlets shall not contain more than the equivalent of four quarter bends, 360 degrees total, including the outlet fittings. Bend radii at the inner surface of the bend shall be no less than eight times the nominal inside diameter of the conduit.

b. All conduit bends and offsets used shall be made by the use of special forms or tools and shall have the largest radius possible so that wires can be pulled without the use of tackle or power.

c. Conduit shall be securely clamped with all runs electrically grounded to make a continuous ground. Conduit installation shall not create situations of dissimilar metals.

d. All conduit shall be arranged to prevent moisture traps and shall drain toward control boxes, except that all open-ended conduits shall be installed in such a manner as to ensure gravity drainage out the end. The conduit arrangement and installation shall be subject to approval.

2. Wireways

a. Wireways shall be located to provide access to the harnesses contained within for maintenance action. They shall be provided with approved covers which may be interrupted wherever desired for entry and exit of wires and cables. Edges of such interruptions shall be completely covered with protective bushings.

b. The wireways shall be routed such that they avoid:

i. Sources of heat such as propulsion and dynamic brake grid resistors;

ii. Wheel splash areas; and

iii. Areas along the vehicle where the trays may be subject to foreign object damage.

c. Metal raceways and the elbows, couplings, and similar fittings shall be electrically and mechanically coupled while protecting wires from abrasion and shall make a continuous ground with the locomotive structure.

d. Bends in wireways shall be avoided; however, if they are required, approved protection shall be provided to avoid insulation chafing at the bends.

e. All wire and cable shall be securely fastened within wireways to eliminate movement and resultant chafing.

21.23 ELECTRICAL DEVICES AND HARDWARE

A. General

1. All electrical devices shall be transit industry-proven.

B. Contactors and Relays

1. All contactors and relays shall meet or exceed the requirements of MIL-R-6106 and MIL-R-5757 respectively, with the following qualifications:

a. Devices shall be tested for proper functioning in orientations up to 30 degrees from the orientation in which they are mounted in the vehicle, in each of the three possible rotations: pitch, yaw, and roll.

b. If adequate documentation exists demonstrating that during functional and operational testing of the vehicle the contactors underwent normal duty cycle tests, it shall be considered as an acceptable alternative to a burn-in.

c. In selected applications, contactors and relays shall comply with the requirements of MIL-R-6106 (for ratings of 10 Amperes or greater) and MIL-R-5757 (for ratings of less than 10 A) but need not be qualified to these documents if all of the following requirements are met:

i. The device is service proven in the exact same application.

ii. The device is service proven in transit service.

iii. All other requirements of this Specification are met.

iv. The Authority approves of this application.

d. All devices shall be constructed and utilized in a fail-safe manner; that is, all failures shall be in a direction so that neither the passengers, the crew nor the equipment are placed in jeopardy.

e. All devices shall be installed so that they are fully accessible for inspection, repair-in-place, or removal and replacement. All contactor terminals shall be fully accessible for trouble shooting purposes. Contactors and relays shall incorporate means of visually determining whether they are picked up or dropped out. Relays on printed circuit boards or within electronic assemblies may be exempted from the requirement for a visual indication, as approved by the Authority.

f. There shall be a maximum of two wire terminations on any one contact of the device.

g. The coils of all devices shall be suppressed to protect the low-voltage network from generated transients.

h. Under no circumstances shall either the main or auxiliary contact tips of the devices be placed in parallel for the purpose of carrying a current load at or above the manufacturer's contact tip rating.

i. Contact tip ratings shall be stated for the worst condition of reduced surface contact which may result from tip misalignment during normal operation of the device.

j. Contactor installation shall be such that the arc spray is directed by an arc chute away from ground and any other electrical devices proximate to the contactor.

k. Devices shall be constructed in a very heavy-duty fashion suitable for use in railroad service. The Authority reserves the right to review and approve the design and selection of all contactors and relays.

l. Contactor tip replacement shall not exceed 10 percent of the total number of tips at ninety (90) day intervals.

m. All contactors shall be constructed so that the main contact tips make and break with a motion (wipe) that prevents deposits and pitting.

n. All DC contactors shall be built with series-fed blowout coils. The Contractor shall demonstrate the ability of each contactor type to reliably interrupt current over the full design operating range.

o. All devices shall be readily identifiable by means of a permanent, durable marking strip giving the device circuit designation. No identifications shall be obscured, or partially obscured, by wire routing. The identification strip shall be mounted adjacent to the mounting of said device.

p. Bifurcated contacts shall be used in low voltage applications, whenever necessary due to dry contacts or low current switching requirements.

q. All time delay relays shall be of the R-C delay or solid state type. No mechanical or pneumatic time delay devices shall be permitted.

r. Where plug-in relays are approved, the relay shall be positively retained by means of a retaining clip or bar. This device shall be captive, of rugged construction and shall be easily positioned for relay installation and removal without the need for special tools. When the relay is removed, the retainer shall itself be retained so that it cannot come in contact with devices which may have exposed energized electrical circuits, and it shall not interfere with the operation of any other device when in this position.

s. Adequate gap and creepage distances shall be maintained from high voltage contactor tips and low voltage coil and auxiliary contacts to prevent entry of high voltage arcs or transients into the low voltage circuits. The same applies to grounded mounting surfaces.

t. Relays shall not be affected by the accumulation of airborne dust.

C. Switches

1. Under no circumstances shall poles of switches be placed in parallel in order to carry

currents in excess of the contact pole rating given by the manufacturer.

2. Switches shall be provided with a "keying" feature so that after installation, the body of the switch is constrained from mechanical rotation.

3. All switches provided shall be of the highest quality procurable and shall be fully suitable for the rigors of the Authority's service environment. All control switches which are subject to water splash, which is defined to mean any switches mounted near windows or doors, or mounted on the Train Operator's control console, shall be environmentally sealed. Toggle and push button switches shall be per MIL-S-3950, MIL-S-8805, MIL-S-83731, or equal. All safety-critical switches, such as those that can cause door openings, shall be designed to withstand a high potential test of 1,500 Volts for 1 second, in a clean, dry condition, without false conduction. The design and selection of all switches shall be subject to review and approval.

4. There shall be a maximum of two (2) wires connected to each terminal of the device.

5. Switches shall be individually replaceable without disconnecting or removing anything other than the mounting fasteners and electrical connections of the switch to be replaced.

6. In addition to the above requirements, all switches and pushbuttons shall meet the following requirements:

    a. Contact resistance shall be less than 0.1 Ohm at 3 VDC and a 10 milliampere load.

    b. Open circuit resistance shall be 50 mega Ohms minimum.

    c. Resistance to case shall be 1000 mega Ohms minimum at 500 VDC.

D. Circuit Breakers

1. General

    a. All circuit breakers provided shall be extremely rugged and fully suitable for the service intended.

    b. They shall be of the highest quality procurable. Design and selection of all circuit breakers shall be subject to review and approval.

    c. All circuit breakers of the same rating shall be of the same manufacture and model throughout the vehicle.

    d. The “ON”, “OFF”, and “TRIPPED” positions of all circuit breakers shall be permanently marked on the handle or the case of the circuit breaker. The circuit breaker, when tripped, shall assume a distinct position between the “ON” and “OFF” positions to permit determination of the fact that it has been tripped by either its over-current or shunt trip elements. All circuit breakers shall be mounted in the vertical direction with the “ON” position up.

    e. Circuit breakers shall be individually replaceable without disconnecting or removing anything other than the mounting fasteners and electrical connections of the breaker to be replaced.

f. Electrical connections to circuit breakers shall either be threaded to accept machine screws or use a threaded stud. Wires to circuit breakers shall use ring terminals.

g. Circuit breaker terminals shall not be used as junction points.

h. Each and every input power circuit shall be protected by an individual circuit breaker. Separate circuit breakers shall be provided for major assemblies or functions. No circuit breaker shall protect more than one circuit, nor shall any one circuit be protected by more than one circuit breaker.

i. All circuit breakers shall be sized by current rating and tripping time to protect both the associated equipment and the minimum size wire used for power distribution within the protected circuit without causing nuisance tripping.

j. High voltage circuit breaker poles may be connected in series if necessary to achieve the stated voltage interruption requirements.

k. Each circuit breaker pole shall be equipped with adequate means of arc extinction to prevent flashover.

l. The continuous current rating of thermal-magnetic trip circuit breakers shall be selected in accordance with ANSI C37.16 for the load and type of service specified.

m. All thermal-magnetic trip circuit breakers shall conform to the requirements of ANSI C37.13 and ANSI C37.14.

n. Circuit breaker current rating shall be clearly and permanently marked and shall be completely visible after installation.

o. Electrically operated circuit breakers shall be arranged for operation from the low voltage dc supply.

2. High-Voltage Circuit Breakers

a. All high voltage circuit breakers shall be devices with not less than 3 poles connected in series.

b. All distribution-type, high voltage circuit breakers shall be Westinghouse Series C, FDB frame, Heinemann type GH, or approved equal.

c. The trip elements shall be thermal-magnetic, or magnetic, connected in series.

d. The circuit breaker handle shall protrude from the circuit breaker panel cover sufficiently to be manipulated in all positions.

3. Low-Voltage Circuit Breakers

a. Low voltage circuit breakers shall be either one-pole or two-pole devices depending on the intended function. Trip elements shall be thermal-magnetic, or magnetic, as is appropriate for the application.

b. All low voltage circuit breakers shall be:

c. General Use - Westinghouse Series C, Quicklag C frame, Heinemann Series AM or approved equal, front connection or approved access arrangement, and approved labeling.

d. Fast Operation - Airpax type IMLK, dust sealed, magnetic breaker, or Airpax type UP, hermetically sealed, magnetic breaker, or an approved equal.

E. Fuses

1. Fuses shall be used only where specifically called for in the Specification or where the use of circuit breakers is not technically feasible, and only with specific approval. Fuses may be considered in applications as follows:

   a. To protect solid state equipment from catastrophic damage, and

   b. Where current or voltage levels prohibit circuit breakers.

2. Fuses shall be permanently identified adjacent to the fuse. The rating of each fuse shall be permanently and clearly marked directly on each fuse.

3. Fuses shall be readily accessible. All fuses mounted in exterior equipment boxes shall be accessible without going under the vehicle.

4. Fuse holders shall contain fuse retention devices at both ends.

5. Air gap and creepage distances shall be as approved. Fuses used in nominal 600 VDC circuits shall be rated for no less than 1,000 VDC.

6. High voltage fuses shall be mounted in totally enclosed, dead front fuse holders, with no exposed high voltage connections. The fuse shall be extracted from the circuit when the fuse holder is opened and the exposed fuse shall be safely isolated from any circuit connection.

7. Where circuits use multiple fuses or fuses and circuit breakers, the coordination between the protective devices shall be discussed in design review.

F. Bus Bars

1. Bus bars are to be fabricated from OFE (Oxygen Free Electronic CDA C10100) or ETP (Electrolytic Tough Pitch CDA C11000) copper. The bus bar conductivity shall be 100 percent IACS. All bus bar joints shall be silver or tin plated.

2. Current densities, other than at joints, shall not exceed 1,000 Ampere per square inch, and in any case shall not exceed a value which would cause a bus bar temperature rise greater than 96ºF. Current densities in joints shall not exceed 150 Ampere per square inch.

3. Bus bars shall be properly brazed together at joints unless bolted connections are found to be absolutely necessary for maintenance purposes and are approved. The overlap at bus bar joints shall be no less than 10 times the thickness of the bus material. Bus bar connection bolts shall be torqued to obtain a uniform bus bar connection pressure of 200 psi. Bolting hardware shall be plated steel with belleville washers to maintain connection pressure.

4. Except for connection areas, bus bars shall be safety-insulated, using a high-dielectric powder coating, heat shrink tubing or other approved means. Tape is not acceptable. Bus bars that are behind insulating panels are exempt from this requirement.

G. Capacitors and Resistors

1. Hermetically sealed, dry tantalum capacitors, in metal cases, shall be used in place of aluminum electrolytics, except for very high values which are not commercially practical or available, in which case long life grade aluminum electrolytics shall be used.

2. Commutating capacitors shall be a paper or plastic film type, shall incorporate a non-toxic impregnant, and shall be chosen to give a service life of at least twenty (20) years. Filter capacitors shall have high ripple current rating for long life.

3. Capacitors shall be derated 20 percent for voltage based on the nominal supply voltage and maximum case temperature. If filter capacitors are exposed to low ripple voltages, lesser values of derating may be accepted if it can be shown that reduced operating temperatures can be achieved due to lower dissipation; however, the sum of the DC and AC ripple voltages shall always be less than the capacitor's voltage rating at a maximum case temperature of 185°F.

4. Except for braking power resistors, all resistors shall be derated 50 percent for power dissipation. Other power resistor applications may be submitted for approval of lower derating, on a case-by-case basis.

H. Transformers and Inductors

1. Transformers and inductors shall be derated 10 percent for current. Transformers shall:

a. Have vacuum-impregnated windings.

b. Be rated to withstand at least twice the maximum peak-to-peak voltage that they shall be subjected to in operation.

c. Not emit audible noise in excess of 60 dB referenced to 20 micropascals at a distance of 2 feet while operating at rated voltage and load.

d. Be designed to minimize radiated and induced EMI.

e. The location, orientation, mounting, cable connections and cable routing shall be in accordance to the overall EMI/EMC control plan for the vehicle.

I. Switch, Circuit Breaker, and Fuse Panels

1. All switch, circuit breaker and fuse panels shall be dead front types mounted in the specified equipment enclosures.

2. Each switch and circuit breaker panel shall carry the necessary apparatus, arranged to be easily accessible to connections and designed to prevent operating or maintenance personnel from coming in contact with live parts when operating the switches or circuit breakers. Furthermore, all live portions of the protected circuitry shall be completely concealed so that no danger of electrocution or shock exists from the touching of the

panel or any appurtenances or devices mounted thereto.

3. All switches, breakers, fuses, and indicating lights shall be provided with a nameplate of raised or recessed lettering on the dead front, clearly identifying the circuit which each controls and its circuit designation. The dead front panel shall conform to NFPA 70, Article 384. The dead fronts shall be made of moisture-proof, electrically insulating, laminated phenolic or fiberglass, of approved quality suitable for switchboards. Asbestos shall not be used.

4. A wiring gutter shall be provided along the top, sides, and bottom, for the routing of high voltage leads to their designated circuit breakers.

5. The panel shall be secured by approved, captive fasteners and shall be configured for easy removal so that maintenance and repair action is not impeded.

6. Power distribution to circuit breakers and switches shall be from a bus bar or bus circuit. Distributing power by successive or "daisy-chained" connections between device terminals shall not be permitted.

J. Battery Backup Circuits

1. Backup batteries are not permitted, unless specifically approved by the Authority.

K. Auxiliary AC Motors

1. All AC driven motors shall be of American manufacture. Motors shall limit starting current to within industry recommended practices and be equipped with NEMA C-frame type sealed bearings that shall not require re-lubrication for the life of the bearing. Bearings shall be sized to provide a minimum life of 6 years.

2. Motor stator insulation shall be IEEE Standard 11, Class H insulation system or better. After assembly, the motor stator coils shall be vacuum pressure impregnated (VPI) in the complete stator frame assembly. A description of the proposed VPI shall be included in the Contractor’s proposal. The stator shall be arranged to permit rewinding. The rotor shall be arranged to permit replacement of the shaft without damage to the rotor.

21.24 ELECTRICAL AND ELECTRONIC DESIGNS

A. General Design Criteria

1. Except as otherwise noted herein, electronic equipment shall conform to IEC 60571, Electronic Equipment Used on Rail Vehicles, Class TX, unless otherwise approved by the Authority.

2. All low voltage apparatus shall function satisfactorily for any duration at any continuous voltage between 55 and 80 volts, measured at the battery, and shall not be damaged or operate in an unsafe manner by the continuous application of voltages below 55 volts. All hardware shall be protected against moisture, oxidation, and common air-borne contaminants. Use of any locking compounds or anti-seize compounds on threaded electrical connections is prohibited. Conveniently located near any removable printed circuit board, or group of such boards, shall be a primary power switch whose opening shall make it possible to remove and replace such boards without injury to them. This

switch may have multiple functions relating to troubleshooting and diagnostics as required. Equipment containing devices that are sensitive to electrostatic discharge (ESD) shall have provisions for hookups, properly identified, for attaching grounding devices. Equipment shall be designed to reduce or eliminate the need or requirement that maintenance crews be grounded during the maintenance of the cars. All circuits on the car shall be designed to impose sufficient current load to positively eliminate any problems from "dry circuit" conditions to the satisfaction of the Engineer.

3. The need for adjustments shall be avoided wherever possible by the use of appropriate circuitry, stable components, and the use of high tolerance drift compensation and temperature compensation circuits. Where adjustments on printed circuit boards are necessary, they shall be accomplished without the use of specialized (i.e., non-catalog US supplier) test equipment unless this equipment is furnished by the Contractor.

4. In general, all return circuits for any one system shall return to a single terminal point, without any connections to returns from other systems. Circuit design shall minimize both circuit complexity and number of components and shall annunciate component failures in a safe manner by responding or not responding, as appropriate, to commands for changes of state. Use of diodes shall be minimized and when used their failure shall not allow an unsafe condition to be created.

5. Electronic equipment shall utilize stock components and shall function properly with the component manufacturer's full range of tolerances such that after-purchase screening or testing of components shall not be required. Matching of components is permitted only if the components are normally available from the manufacturer in matched sets.

6. Equipment design consideration shall include separation of high voltage from low voltage devices. Components shall not be located near or above high voltage contactors. All low voltage components, controls, circuits and mounting hardware near or in the arc path of contactors shall be adequately protected against damage either by insulating material or by adequate distance.

7. All fiber optic cables shall be installed in accordance with the cable manufacturer's instructions, shall be adequately protected from damage of any kind, and shall be readily accessible for maintenance and inspection. Fiber optic terminations shall be designed to prevent degradation due to the car environment, including vibration and variation in temperature, and shall be capable of inspection and repair without removal from the car. Fiber optic cables shall be provided with a minimum of 10 percent spares on a location-to-location basis. Samples and technical details of all proposed fiber optic cables and connectors shall be presented to the Engineer for approval.

8. Capacitors shall be derated at least 20 percent for voltage based on the nominal supply voltage and maximum case temperature except for the DC link capacitors in the propulsion system which shall be derated at least 10 percent. Hermetically sealed metal-cased dry tantalum capacitors shall be used in place of aluminum electrolytic capacitors, except for very high values which are not commercially practical or available or where otherwise not appropriate, in which case long life grade aluminum electrolytic capacitors shall be used or in cases where tantalum is technically inappropriate. Alternates with equivalent service life may be approved on a case-by-case basis. Commutating capacitors shall be a paper or plastic film type and incorporate a nontoxic impregnant, and shall be chosen to give a service life of at least 20 years. Filter capacitors shall have high ripple

rating for long life, and the sum of the DC and AC ripple voltage shall always be less than the capacitor's voltage rating at a maximum case temperature of 185 degrees F. All high voltage filter capacitors, shall make use of bleeder resistors and/or other techniques to ensure their reduction to less than 50 volts within 1 minute in the absence of car motion and externally supplied power. The methodology details and expected results shall be submitted to the Engineer for approval during Design Review. The resistors and their installation method shall be such as to ensure long life.

9. Except for accelerating and braking power resistors (unless determined to be necessary), all resistors shall be derated 50 percent for power dissipation. Transformers (other than the main transformer) and inductors shall be derated at least 10 percent for current, or other appropriate approved factor, based upon the duty cycle. Circuit design shall employ protective techniques such that failures in power semiconductors shall fail safe or fail open, and not cause consequent failure of components or major devices following them in the circuit. Except for the case of integrated circuits, or where environmental conditions make it a necessity, as exempted by the Engineer, no module employing multiple components shall be made nonrepairable by potting.

B. Hardware

1. Refer to Part 21.23 for general hardware requirements. All hardware associated with electronic and electrical control systems shall be protected against moisture, oxidation, and common airborne contaminants. Hinges and latches shall be of stainless steel.

C. Enclosures/Racks

1. All circuit boards that are rack-mounted shall plug into racks containing the mating half of the circuit board connector. The circuit board rack shall mount in an enclosure conforming to requirements in this document. The rack, circuit board, and circuit board hardware shall be designed as an integrated system.

2. The rack and enclosure shall provide environmental and EMI shielding as required to meet the requirements of this document.

3. Printed circuit boards shall be positively retained by means of keeper bars or other approved method. The enclosure or rack cover shall not be used to retain the circuit boards, unless specifically designed to do so.

4. Each circuit board shall be fitted with an ejector or hand grip to assist in board removal. The rack and the edge of each board, or the card ejector, shall be labeled with corresponding numbers to identify board location within the enclosure. A brief functional designation shall also be included on each label.

5. The enclosure/rack shall not be connected to the power supply return or signal circuit, unless approved by the Authority.

6. Where it is necessary to use printed circuit boards that are not plug-in and not mounted in an enclosure, the following additional requirements apply:

a. The PC board must be protected from mechanical damage and hostile environments such as arc discharge or contact with high voltage.

b. If the PC board is part of a high voltage circuit, special caution shall be used in its design with regard to strike distance and creepage in the transit vehicle environment. This includes between PC board components and with respect to any grounded mounting surfaces.

c. Any test points required in routine testing or fault isolation to the user replaceable level shall be easily accessible with no disassembly or tools.

d. If replacement of the PC board is required (as part of secondary maintenance), no special tools or soldering shall be required.

7. Each PC board use and application of this type is subject to the Authority approval.

D. Optical Fibers

1. Any application of optical fibers shall be approved prior to implementation. This approval is not intended to discourage the use of optical fibers. Rather, it is to verify reliability and maintainability of the proposed application. In no case shall the on-car repair of an optical fiber require sophisticated or complex polishing and alignment. The connections between optical fibers and car-replaceable units shall be via approved "quick disconnects".

21.25 SEMICONDUCTOR STANDARDS

A. General

1. Semiconductors shall be selected to withstand all continuous and transient voltage and power demands present in the circuit application without damage or reduction in life. All circuit designs shall provide for the presence of high current switching equipment on the vehicle and the resultant induced voltages and currents in electrical equipment.

B. Ratings

1. Semiconductors, except diodes (see below), operated from the battery supply, or those connected to trainlines, shall have minimum breakdown ratings of four times the maximum achievable circuit voltage. Suppression devices shall be provided as necessary to protect the devices and limit the circuit voltage.

2. Diodes operated from the battery supply, used as suppression devices, or connected to trainlines shall have a minimum breakdown rating (PIV) of 1,000 Volt. Diodes with less than 1,000 Volt PIV rating may be used if adequate circuit transient protection is also provided.

3. All discrete semiconductors operated from inverters or other isolating devices shall have a minimum breakdown rating of two times the maximum circuit voltage, except where specifically detailed otherwise. Suppression devices shall be provided as necessary to protect the devices and limit the circuit voltage.

4. All semiconductor junction temperatures shall be limited to 257°F (or to the maximum rated temperature for the device, whichever is less) or less at maximum ambient temperature and at maximum rated output power.

5. All semiconductors shall be operated at less than 50 percent of the maximum continuous current rating or 50 percent of the maximum continuous power rating, whichever is more restrictive. High power/current devices may be exempt from this requirement with prior approval, on a case-by-case basis. The Contractor shall submit complete device information, including all manufacturer's application recommendations, and calculated current and power demands with all waiver requests. If approved, such waivers do not reduce other requirements, including reliability.

6. Integrated circuits operated from the battery supply through inverters or other isolating devices shall be operated within the voltage and current ratings specified by the manufacturer, de-rated to less than 50 percent of the maximum stress level at the maximum operating temperature of the device as specified by the manufacturer.

7. Where the supplies to integrated circuits are regulated and surge protected, the voltage rating shall be 15 percent below the manufacturer's recommended maximum. In addition, the maximum power shall be limited to 50 percent of the manufacturer's specified maximum at the maximum operating temperature.

8. Silicon semiconductors shall be rated for operation over the temperature range of -40°F to 185°F, and shall be hermetically sealed to the extent required by the application.

9. All Gallium Arsenide and similar optical semi-conductors shall be rated for operation over the temperature range of -40°F to 185°F.

C. Component Burn In

1. All plastic semiconductors shall be burned in and screened for defects to a level equivalent to MIL-STD-883, Method 5004, Reliability Class B, or approved equivalent. The method used SV 16.0 16 - 32 Conformed Version – April 2009 must be submitted to the Engineer for approval. As a minimum, the supplier shall have had a proven effective component screening and burn-in program in effect for 5 or more years. Alternative methods based on a minimum 100 hour burn-in for the completed device which uses the semiconductors will be considered. The burn-in must be performed with the equipment operational (power on) and with the necessary input signals and loads to simulate the maximum power dissipating condition in the device at the maximum ambient temperature. Hermetic semiconductors shall receive screening and burn-in to procedures that can be documented to have produced assembled product reliability in accordance with the overall system requirements in this specification.

D. Availability and Identification

1. All semiconductors shall be available from at least two manufacturers and available from U.S. distributors. Single source devices, such as high voltage power devices, microprocessors, ASICs, and related support chips may be used only if approved by the Authority. Such devices shall be essential to the proposed equipment, shall meet the proven service requirements, and shall be supplied by veteran manufacturers likely to support the device.

2. Each device shall be labeled to identify both the manufacturer and the complete part number. Operational characteristics of the device shall be published and available to the Authority.

E. Other Prohibitions

1. Electronic equipment shall utilize stock components and shall function properly with the component manufacture's full range of tolerances such that after-purchase screening or testing of components shall not be required.

2. Matching of components is permitted only if the components are normally available from the manufacturer in matched sets.

3. Germanium semiconductors shall not be used.

21.26 PRINTED CIRCUIT BOARD STANDARDS

A. General

1. Printed circuit boards shall be designed, constructed and inspected to EN standards and/or ANSI/IPC-D-275, latest revision, except where more stringent requirements are noted here. Within ANSI/IPC-D-275, printed circuit board classes are designated. Printed circuit boards supplied under this Specification shall be Class 2, minimum, with the exception of wayside computers that are not utilized in vehicle operation. Class 3 requirements shall apply to all vital equipment.

2. Circuit board material shall be per NEMA Standard LI 1, Type FR-4 (MIL-P-13949, Type GF), for boards which have no components whose power dissipation is greater than 2 Watts and when said board is not mounted adjacent to components dissipating greater than two watts. Otherwise, circuit board material shall be per NEMA Standard LI 1, Type FR-5 (MIL-P-13949, Type GH).

3. Printed circuit boards shall have a minimum thickness of 0.0625 inch base material. All conductor material shall be copper and shall be firmly attached to the board and shall be resistant to blistering and peeling when heated with a soldering iron.

4. All printed circuit boards shall be designed for ease of testability per ANSI/IPS-D-275, "Testability design check list".

5. Traces shall be made as wide as practical, with the minimum width being based on a 18°F temperature rise.

6. Components with pins shall be mounted only on one side. Connections shall be made to the other side or internal layers via plated through holes. SMT devices may be mounted on both sides if part of an approved existing design.

7. All circuit boards shall be inherently stiff or shall be reinforced to prevent damage due to vibration or handling. Circuit boards larger than 100 square inches shall be centrally stiffened unless otherwise approved.

8. All printed circuit boards with the same function shall be interchangeable between equipment groups without additional adjustment.

9. All printed circuit boards shall be of the "plug-in" type, with positive support against vibration. Single board applications, where approved by the Authority, may be of a "non-plug-in" type.

10. Printed circuit boards shall be designed for insertion and removal with power applied, except where power is removed by a switch adjacent to the card rack and except where the mechanical construction would generally prohibit removal and insertion with power applied. Where a switch is used, it shall be labeled with a warning regarding its proper use.

B. Marking

1. All circuit boards shall be labeled with a part number, serial number, and descriptive nomenclature.

2. All components shall be labeled on the board with component drawing references and such other information as may be required to repair and troubleshoot the board, except as approved by the Authority. The component and wiring sides of the board shall each be marked to indicate capacitor and diode polarity, and at least two leads or one lead and a graphic symbol indicating orientation of all transistors and thyristors.

3. Integrated circuits and other multi-terminal devices shall have an index mark on the component side of the board, visible with the component inserted, to indicate proper keying and insertion; additionally the first pin on all IC packages shall be identified on the wiring side of the board. The labels used to identify components on the printed circuit board shall match those used in the schematic drawings for that particular component.

C. Component Mounting

1. Components shall be fastened to the board in such a manner as to withstand repeated exposure to shock and vibration. Large components shall be supported in addition to the solder connections. Power resistors shall be mounted on standoffs so that the resistor bodies do not contact the board, spaced far enough away from the board so that resistor produced heat shall not discolor or damage the board.

D. IC and Device Sockets

1. IC and device sockets are prohibited except for components that must be removed for reprogramming or initial calibration procedures or devices that are available only in mounting in sockets. All socket applications are subject to the Authority approval. All other components shall be soldered in place.

2. Where approved, IC sockets shall comply with approved standards such as MIL-S-83502 and MIL-S-83734, as is applicable for the device, and shall be made of the following materials:

3. The bodies shall be molded from diallyl phthalate, PTFE Teflon, or approved equal.

4. The contacts shall be fabricated from beryllium copper and shall be plated with a minimum of 0.000030 inch of gold over a minimum of 0.000050 inch of low stress nickel in the area of contact with IC pins.

E. Conformal Coating

1. Both sides of the assembled printed circuit boards shall be coated with a clear insulating and protective coating material conforming to MIL-I-46058 latest revision, or approved

equal.

2. The Contractor as part of the recommended spares submittal, shall include a list of recommended printed circuit boards which shall remain available for the life of the locomotive.

F. Keying

1. All printed-circuit boards shall be mechanically "keyed" to prevent insertion into the wrong slot or in the wrong orientation. Further, circuit boards in safety related control systems, such as friction brakes, cab signal, ATC, ATS, and systems which can cause damage or unsafe train operation if the vehicle is operated with a card removed, shall be connected through a safety circuit to disable the vehicle if a circuit board is removed.

G. Circuit Board Connectors

1. Printed circuit board connectors shall be heavy duty, high reliability, two-part type with a history of successful service in rail applications and shall be approved by the Authority prior to commencing design.

2. Connectors which comply with MIL-C-55302 or DIN 41612 Level 1 or 2, and which have plated contacts as described below, are considered to comply with the requirements of this section.

3. The connector contact area shall be plated with a minimum of 0.000030 inch f gold over a minimum of 0.000050 inch of low stress nickel.

4. Card edge connectors are prohibited.

H. Testing

1. Sufficient clearance shall be provided between components to allow testing, removal, and replacement without difficulty due to lack of space.

2. Test points shall be provided in appropriate locations on modules and printed circuit boards. A negative return test point shall also be provided. The test points for manual testing shall either accept and hold a standard 0.080 inch diameter tip plug or shall be a turret lug similar to Cambion No. 160-1026-01-05, or approved equal, with sufficient clearance to permit it to accept a standard oscilloscope probe clip, and shall be identified by appropriate markings.

I. Extenders

1. Printed circuit board extenders shall be provided by the Contractor for test purposes. At least two extenders of each type shall be available for use and evaluation throughout the design conformance and acceptance test programs and shall be delivered to the Authority upon the acceptance of the BTE. The interfaces between extender and enclosure and PC board must be positive and secure and must prevent malfunction and falling out during testing. Mechanical locking means shall be considered on large PC boards.

21.27 INTERFERENCE AND TRANSIENT SUPPRESSION

A. All electrical devices and wiring shall be carefully planned and selected to avoid electrical interference in the operation of the propulsion and braking system, train radio, public address and any other frequency sensitive systems. This shall include the use of shielded cables, chokes, filters, and capacitors, as required by good design standards, to avoid possible interference with these systems. Adequate voltage transient suppression shall be provided for the protection of panels and circuitry involving semiconductor devices. Low voltage circuits shall be capable of withstanding 1.5 joules, unless otherwise approved by the Engineer.

B. Apparatus creating EMI emissions shall be designed to contain these emissions within their package area. Suppressors shall be incorporated across inductive devices to minimize switching transients. All suppression devices shall be selected on the basis of their ability to absorb the amount of energy available in the connected circuit, for the number of cycles of operation expected in service, without requiring replacement prior to scheduled overhaul. All magnet valves and relay/contactor coils shall have free-wheeling diode or metal-oxide varistor voltage spike suppression, or other suppression means, except where this results in deterioration of performance. Coil suppression devices shall be located physically on or as close as possible to the coil it protects (preferably directly at the coil terminal). Wherever possible, the suppression of transients shall be at the source

21.28 SOFTWARE AND SYSTEMS

A. General

1. This section includes requirements at the systems level as well as the software and related hardware levels. The systems level includes the overall car level and the individual systems level.

2. All software and related electronic hardware for this project shall be subject to the requirements of this Section. This includes, but is not limited to, software systems for control, monitoring, diagnostics, portable test equipment, and wayside data analysis. No exception is made for items that may be considered firmware. Systems that include data files or configurable or customizable components such as Field Programmable Gate Arrays (FPGAs) are also covered by sections below.

3. The specific application requirements for the individual systems are given in the corresponding sections of this Specification while the common requirements, pertaining to all such software systems, are given in this section. The additional requirements given here include both design requirements and documentation requirements.

4. The major goals for this section are to assure that these software systems are complete, reliable, require few if any changes late in the development cycle, are provided on schedule, and are changeable in the future without compromising design integrity. To achieve these goals, plans are needed early in the project; the requirements for software must be analyzed; and designs developed that meet all the requirements.

5. Documents shall need to be read by numerous people during development and in the future for problem analysis and changes. It is important therefore, that all documentation be easily and unambiguously readable.

6. The Sections below require first, that the overall functions and design structure of the locomotive systems be described along with the internal breakdown of the systems into

software and hardware components.

7. Later sections below give requirements for the software and hardware components, as well as for how they shall be documented.

8. The software must be treated as an integral part of the total system design and shall be reviewed as part of each design review for the corresponding systems.

21.29 SYSTEMS REQUIREMENTS

A. General

1. The Contractor shall be responsible for the overall design and for the integration of the systems into the complete system. Each subsystem is then designed and documented by the supplier with the Contractor reviewing the designs and testing the completed systems.

B. System Documentation

1. Contractor's Overall SFD

a. The Contractor shall provide an Overall System Functional Description (Overall SFD) that shall define hardware and software components, the partitioning of the system functions, and the allocation of requirements (including derived requirements) to the individual Systems.

b. The Overall SFD shall include a diagram of the complete system to be provided. It shall show the systems with their interfaces including network interfaces. The terminology of the overall SFD document must be consistent with that of this Technical Specification. The locations of systems within the locomotive shall also be shown in diagrams and described.

c. The allocation of requirements to multiple systems shall be clearly described with attention to derived requirements such as the allocation of timing requirements that together provide an overall timing requirement.

d. The SFD shall define any commonalities between the systems such as networking standards or other shared interfaces. Interface Control Documents (ICDs) shall be used to document all significant interfaces between systems. The ICDs shall conform to IEEE Standard 1558-2004.

2. Individual Systems SFD Required Content

a. For each individual System, the Supplier shall provide a System Functional Description (SFD) that completely describes the system and how it meets the project requirements. These SFD documents shall be consistent with the overall SFD and with this Technical Specification.

b. The SFDs shall provide the following:

i. A Context Diagram showing the system and the external interfaces. There shall be an accompanying description of the functions of the system and the relationships of the system with other systems.

ii. A Decomposition Diagram and Description shall describe all System Components and internal interfaces.

iii. Each hardware component shall be described to the level of its major components, LRUs, LLRUs, the functions to be performed, and the interfaces.

iv. The components shall be further broken down to the Hardware Components, Software Configuration Items, the internal interfaces within the system, and the external interfaces to other car level systems.

v. Each Software Configuration Item (SCI) shall be described in its own numbered section. The major functions of the item shall be described and the relationship to the hardware including memory and input/output hardware. The power fail shutdown strategy shall also be described.

vi. A Software Summary Table with a row for each software item in the system, including proposed Commercially Available (CA) items. Columns shall give the Software Configuration Item name and ID, Software Requirements Specification (SRS) name and ID, Software Design Description (SDD) name and ID, and section within the SFD where the SCI is described. The use of the proposed CA items and their classification as CA for the purposes of this project shall require approval.

vii. The descriptions of hardware items shall also include explanations of how the hardware requirements of the Technical Specification shall be met.

viii. For Programmable Components such as FPGAs, Complex Programmable Logic Devices (CPLDs) and other similar devices, all specific hardware and programmed functions and the interfaces shall be defined in a dedicated section. This description must include the requirements to be met by the item. The detail design for those items shall then be documented separately in the schematics or in an appropriate application file and output file of the software tool used to program the device. If data files are to be separate configuration items, their content must be described also.

c. A Failure Detection and Remedial Action description section shall describe monitoring the correct operation of system components, the failures to be detected and the remedial actions for minimizing the impact of the failure. Failure detection should facilitate root cause analysis, and repair. The description shall include the detection of sensor input failures and compensation schemes such as the use of alternate sensors or performance restrictions.

3. Testability

a. All features and functions of software systems shall be testable on a systems level. Specific approval is required for any feature that is not testable on a systems level. For features that are only testable with special equipment, all such equipment shall be supplied by the Contractor as special test equipment and become the property of the Authority. This equipment shall provide the logic, sequencing, and emulation necessary to verify that the software functions as intended. In lieu of separate equipment, appropriate test functions may be provided within the Portable Test

Equipment (PTE).

b. Type tests of all processor systems shall verify the proper operation of all software features, including component failure detection and diagnostics.

c. All Test Plans and Procedures shall be submitted for approval prior to conducting the tests. Each requirement of the SRS must be traceable to the test procedures using the Software Requirements Traceability Matrix.

C. Software

1. General

a. The requirements of this section pertain to all subcontractors providing software (including Programmable Devices). If the Contractor shall supply software for this project then they shall also be considered a Supplier and shall also be subject to the requirements of this section pertaining to suppliers.

2. Contractor and Supplier Qualifications

a. The Contractor, as systems and software integrator, and suppliers who are providing processor-based products shall have a mature software development process. To confirm its capability, the Contractor shall submit an independent Software Capability Evaluation (SCE) for themselves and for each supplier. Even if the Contractor shall not directly produce software, the overall software design, integration, and subcontract management are critical to the success of the project. Consequently, the Contractor's SCE is still required. In each case the SCE must cover the entire range of activities, by the Contractor/Supplier, relevant to the project.

b. The independent evaluations shall include the use of a lead assessor who is certified by the Software Engineering Institute (SEI) and shall be conducted according to the methodologies established by the SEI. A ranking in accordance with the Capabilities Measurement Model (CMM) shall be developed for the Contractor and each supplier of software. Previous rankings from calendar year 1999 or 2000 may be used without a new evaluation. The Contractor's evaluation report and each supplier's report must be provided to the Authority for approval 120 days after NTP and concurrent with the submittal of the quality assurance manual per Part 24.00.

c. If the Contractor's ranking is below CMM level 2, and for each supplier with a ranking below CMM level 2, a course of action must be defined to mitigate the impact of the problem areas on the project and to improve the processes to at least a CMM level 2. To this end the Contractor or supplier shall submit for review and approval the following along with the SCE report described above:

i. An impact report describing how each of the problem areas identified in the SCE report would impact the project.

ii. A remedial action plan defining the activities, resources, and schedule the supplier shall commit to for improving their operation and achieving a level 2 or greater CMM rating on a subsequent evaluation. The plan shall be based on the SCE findings and shall prioritize the efforts to maximize the benefits to

the project. The plan must include the completion of all required activities and successful reevaluation at CMM level 2 or higher before the contract closeout.

iii. A project specific interim plan. For problem areas where the above remedial action plan cannot result in permanent process improvements in time to affect the project, specific procedures, reviews, reports, or other activities for the project shall be defined to compensate in these problem areas.

d. The contractor shall submit monthly progress reports identifying progress to plan on the above and any changes to the plans. The reports must demonstrate a concerted effort and tangible results. Reports shall continue up through the submittal of the final SCE report confirming a level 2 rating.

3. Software General Features

a. Software shall perform the following basic functions:

b. Implement the desired control scheme or other functions such that the specified performance is achieved;

c. Monitor all inputs for unsafe, erroneous, or unknown conditions or combinations of conditions and take appropriate actions to preserve proper functioning and capture appropriate information to facilitate root cause analysis and repair.

i. Sample all input conditions and hardware status at rates sufficient to detect and remedy all unsafe or damaging conditions in the shortest possible time. Sampling rates and program execution times shall be such that the control system is not the limiting factor in response to unsafe or damaging conditions. All software shall be designed to ensure that the timing requirements for safety-related tasks are always met;

ii. Limit all output commands to safe levels regardless of any combination of input conditions;

iii. Perform self-diagnostic routines and respond promptly, safely, and predictably to detect faults. The self-diagnostics shall include tests for program corruption and for integrity in read/write memories;

iv. Respond safely and predictably when powering up or recovering from power interruptions. All power interruptions likely to have corrupted temporary storage shall be detected and cause the system to re-initialize all affected routines and temporary data. Detection of power interruptions may be by hardware; and

d. Permit thorough interrogation of all input, output and internal conditions by external diagnostic equipment.

e. Software shall be designed to minimize the interaction between functions and reduce the coupling such that changes in one area are unlikely to affect other functions.

f. Programs shall be modular with separation of Operating/Executive Software from Application Software. Software version numbers shall be included within the code.

Programs stored in sets of memory devices must self-test to assure that the correct complement of devices is installed. Software shall have verifiable version control based on a Cyclic Redundancy Check (CRC-32) polynomial published in the software documentation and verifiable using an approved utility. This utility shall be included in the Portable Test Units (PTUs), Software Workstations, and the Monitoring and Diagnostic System (MDS). When requested by these systems, the software shall calculate the CRC-32 value and report it along with the version ID. The CRC-32 value shall be provided with each release of a Software Item.

g. Processor system parameters shall be adjustable via PTE. Appropriate parameters shall be suggested by suppliers during design review for approval. User defined/changeable parameters shall be structured as tabled data. Allowable ranges of parameters shall be stated in the SRSs as requirements and the software shall restrict setting of parameters to these ranges.

h. In the event that vital functions are performed in processor based systems, functionality shall be verified in accordance with IEEE STD 1483-2000, "IEEE Standard for the Verification of Vital Functions in Processor-Based Systems Used in Rail Transit Control".

4. Software Activities

a. The Contractor and Suppliers must plan the activities they intend to perform in order to provide the required software and related documentation. These plans must be documented and submitted to the Authority so agreement can be reached regarding them. Plans must include schedule and resource allocations sufficient to meet the submittal requirements of the Technical Specification. Progress shall then be monitored according to the plan to assure on-time delivery and assure the software meets all requirements.

b. Software Requirements Analysis must be performed for each Software Configuration Item to determine all requirements from all sources. These requirements must be documented in a SRS and submitted for review. The requirements analysis must be performed early in the process to allow for general review and to allow the design to be developed considering all requirements. A Software Test Plan shall also be developed at the time of requirements documentation.

c. Software Design shall include software design activities and documenting the design.

d. The reuse of software from previous applications is encouraged, as long as the full set of requirements in this Contract are addressed. This includes both functional requirements and requirements of this Section such as those for language, structure, maintainability and error detection. Requirements analysis, design, and the documentation of both are needed regardless of the intended re-use of the software items.

e. Suppliers must conduct formal reviews for each document with review minutes submitted along with the documents.

5. Software Documentation

a. General

i. Software documentation shall be in accordance with IEEE Standard P1558-2004, "Standard for Software Documentation for Rail Equipment and Systems" and with the additional requirements set forth within this document. The IEEE 1558 requirements shall be for a type 5 system as defined within that standard.

ii. Some software items may be classified by the Authority as Commercially Available (CA) for this project. Requirements for these items are given in the Technical Specification.

iii. The Authority shall be provided with sufficient documentation to fully comprehend and analyze the operation of the equipment in which the software is to be installed.. The documentation shall describe how all requirements shall be met. Software documentation training shall be included within the formal Training Program. Submissions shall also conform to the requirements of the procurement contract documents.

b. Application Software

i. All documents shall be in a common format within the set of Contractor documents and within each of the sets of documents from each Supplier. These formats shall use a consistent set of graphical and textual techniques to fully describe the software functionality and implementation.

c. Contractor Requirements

i. The Contractor shall develop and submit for approval a Software Project Management Plan (SPMP), a Software Quality Assurance Plan (SQAP), a Software Configuration Management Plan (SCMP), and a Software Verification and Validation Plan (SVVP), all in accordance with IEEE Standard 1558-2004. The scope of these documents shall cover the entire software development for the project. These documents shall be submitted for approval soon after the NTP, before the submittal of other documents. The Contractor Software Verification and Validation Plan (SVVP) shall describe the integration of the subsystems to cover the requirements of the entire system.

ii. An SVVR is also required with each Software release presenting the Contractor V&V activities.

d. Supplier Requirements

i. Each Supplier shall create and submit the full set of documents conforming to IEEE Standard 1558-2004 Standard for Software Documentation for Rail Equipment and Systems for type 5 as defined in that standard.

ii. All documentation shall use names and acronyms consistent with those in the Technical Specification and as defined in the Contractor Overall SFD and the

SFD for the specific system.

iii. The problem reporting and corrective action process shall provide reports allowing the easy tracing of problems found at each development stage back to changes in the requirements, design or implementation in source code.

iv. Each software release shall be provided in a package including a consistent set of up to date and approved software documents, test reports, the updated SVVR, and a Software Version Description (SVD).

v. All references to documents shall specify the location to a sufficiently specific section of text so the reader can easily and unambiguously understand the intention.

vi. All source code, including comments, shall be in English. Source code must be well structured, modular, and clearly documented to allow easy comprehension and straightforward traceability to the SDD documents. Software comments shall also include explanation of all significant memory addresses such as interrupt vectors, I/O addresses, and memory locations for RAM, ROM, and other memory devices. Files and modules must have headers describing functions, interfaces and change histories. Proposals for escrow agreements shall be considered according to the Terms and Conditions of the Contract.

vii. All documents shall be submitted as separate documents, not as internal to other submittals such as the PDR, In-Progress Design Review (IPDR), or CDR documents. All documents shall use names and acronyms consistent with those in the Technical Specification and as defined in the Contractor overall SFD and in the individual system SFDs.

viii. The Contractor shall assure that the documentation produced provides for the straightforward traceability of requirements of the Technical Specification throughout the design documentation and final test. This shall include derived requirements as well.

e. Additional Requirements for Software Documents

i. Software Project Management Plan (SPMP)

(a). Details shall be provided describing monitoring of Supplier activities to assure development tasks are completed and delivery requirements are met for each development phase from concept development to warranty support. It shall describe the procedures used to conduct software quality audits for suppliers and subcontractors.

(b). The Software Project Management Plan (SPMP) for both the Contractor and the suppliers shall include a schedule showing the key tasks defined for the software development. A Gantt chart shall be used showing the timing and interrelationships between tasks. This schedule shall include the allocation of time and resources for realistically addressing issues raised by internal reviews, Contractor reviews, or by the Authority. The

SPMP shall include detailed descriptions of the metrics to be used to monitor and control the project. This shall include monitoring project progress on intermediate tasks and triggering management corrective actions with sufficient time to assure required deliveries are met.

ii. Software Verification and Validation Plan (SVVP)

(a). The supplier's Software Verification and Validation Plan (SVVP) shall require internal peer reviews of each version of the documents and source code. Summary reports of these reviews shall be included in the Software Verification and Validation Report (SVVR). For each review it shall also state the version of the items reviewed as well as the versions of all related documents used in the review. These include, for example, documents that the subject item was reviewed against such as an SRS or related interface specifications used in the review of an SDD. The review reports shall list for each V&V task, the type of review, the participants, the date, the versions of all items used in the review, and all issues from the review. The SVVP shall also require reviews of each design or source code change prior to test and release. Summaries of these also are required in the SVVR.

(b). Similarly, test reports summaries shall be included in the SVVR and they shall identify the version of the SCI tested, the test plans, and the versions of all additional items used in the test.

iii. Software Requirements Traceability Matrix (SRTM)

(a). The Software Requirements Traceability Matrix (SRTM) shall provide cross-referencing between the requirements of the SRSs and the corresponding sections of the SFD, SDD/ICD/DBDD, and the Software Verification Test Procedures. It shall include one table for each SCI and within each table there shall be a row for each SRS requirement. The columns shall include the unique identifier for the individual requirements defined in the SRS, a short description of the requirement, the reference to the corresponding SFD section, the reference to the SRS section, the reference to the SDD section or sections, and the reference or references to the Software Validation tests. Since the references are dependent on the version of the documents referenced, the specific versions of all referenced documents must be stated for each table.

(b). All references to documents shall specify the location of the pertinent text to a sufficiently specific section so the reader easily and unambiguously understands the intention.

iv. Software Version Description

(a). SVDs shall be provided with each version of the software items. Each SVD shall include a description of the problems addressed or features added, changes to software requirements, changes to the software design, , a record of review results for each pertinent document, test plan changes, and test results. The SVD shall be submitted to the Authority

before use of the software in official tests or on the locomotives.

f. Escrow Account

i. The placing of software design documentation details, such as proprietary source code or compilers, in a third-party escrow account, in lieu of submittal to the Authority, may be permitted, subject to Engineer approval, provided that sufficient software information is provided (submitted and/or shown to an approved reviewer) to enable the Engineer to evaluate overall system performance. The Contractor shall conduct a software escrow verification test for all escrowed software. These tests, at a minimum, shall verify that all software and developmental tools have been escrowed to compile, link, or otherwise generate the firmware, object code, P- Code, executable code, or whatever is required to run on the vehicle system or portable test equipment or other software-based system supplied by the Contractor or its subcontractors. The escrowed software design, documentation details, source code, etc., shall be made available to the Authority for its own use if the Contractor or its sub supplier is no longer in business, or no longer supports the product and has not transferred the rights to the design to another entity, or if, based on an independent third party assessment, the Contractor or its sub supplier no longer supports the product at a reasonable cost. The Authority shall be granted a no-cost license to use and maintain all software required to operate or maintain the cars for the car lifetime.

g. Operating Systems and Languages

i. Software may be written in a high or low level language although high level languages are preferred. The language, and its implementation for the selected microprocessor system, shall be commercially available in English. No proprietary languages or code generating systems shall be allowed. All languages and operating systems must have an acceptable installed base and be approved. Languages shall be described in the Methods, Tools, and Techniques sub-clause of the Suppliers SPMP.

D. General Market Software

1. Some software supplied under this procurement may be purchased by the suppliers from external sources and commercially available to a wide variety of users. Examples include operating systems and data base software for fault analysis. The Contractor shall submit for approval a list of software that is commercially available to the general public and which the Contractor and supplier would like to be considered Commercially Available (CA) for this project. This category does not include supplier software.

2. For Commercially Available software, software documentation requirements are limited to: the original data storage/transfer media (CD-ROM or diskette), functional and usage details, all provider manuals, and licenses required for the Authority site use for all hardware provided under this Contract. The requirements and interfaces shall be documented in a specific section of the SFD for that component of the system. References to specific sections of the provider’s documentation shall be included for all requirements. The Contractor shall incorporate training on how the software is to be used in the specific situation for which it was provided as part of the Training Program.

E. Time and Date Processing

1. All systems provided under this procurement, whether acting separately or in combination, must properly process all times and dates within the required span of years from 2000 to 2100 inclusive. This includes all car-borne software as well as all PTUs, Development Systems, Operating Systems, and workstations.

2. The Contractor and suppliers shall be required to provide robust designs and to establish, through both analysis and test, that the product shall process times and dates correctly. An example of a design that may not correctly process dates throughout the required range is storing time as seconds past 1-1-1970. This technique must either not be used or, if used, must be extended to correctly process all required times and dates. Requirements for proper time and date processing must be included in the SRSs for all systems for subsystems that use times and dates.

3. Since setting the time and date is required as part of the normal operating of the locomotives and is required for system validation testing, the design must allow for setting of the time for the

4. whole system or for any part of the system, forward or back, to any time in the required span of years, without incorrect operation or loss of data.

F. Hardware

1. Hardware Platform

a. Microprocessor-based systems shall be based on an established family of microprocessors in wide use in the control system industry. They shall be supported by a full range of software development languages and diagnostic programs. Any use of commercially-available computer boards must be specifically approved. Such approval shall be based upon a technical review of the product, product documentation, and a commercial assessment of product availability.

2. Electrical Isolation and Pre-processing

a. The control system shall be powered by dedicated transformer-isolated power supplies driven from the low voltage distribution network.

b. All control system input and output signals shall be through isolation buffers. High voltage inputs and outputs shall be isolated external to the microcomputer card rack. Low voltage (battery and logic voltage level) inputs and outputs shall be isolated via buffer cards in or external to the microcomputer card rack. The isolation buffers shall:

i. Protect and isolate the control system from damage due to over-voltage, under-voltage, transient, shorts and opens;

ii. Perform necessary voltage translations;

iii. Remove noise and undesired signals;

iv. Limit, pre-process, discriminate and format those signals that would otherwise

require excessive processor time; and

v. Consist of optical isolators, transformers isolators, and other circuits appropriate to the application. Voltage divider circuits shall not be allowed.

3. Program and Data Storage

a. Program code and fixed data shall be stored in a form of PROM. All EPROM windows shall be covered with labels that are opaque at the Ultraviolet (UV) erasing wavelengths. Flash PROM circuitry shall be configured so that reprogramming can be disabled via a semi-permanent hardware mechanism. After the software design has stabilized in revenue service, flash PROM reprogramming shall be disabled. The approved hardware key shall be a small electronic device that attaches to a parallel port or other similar interface on the laptop Personal Computer (PC) used for the PTE. The laptop PC shall interact with the hardware key so as to allow loading of software to the locomotive subsystem only if the hardware device is attached. If a system does not disable flash PROM reprogramming in the equipment itself, then it is acceptable to use a PTE where both a password and an approved hardware key are necessary for the PTE to download software. The same hard key shall be used for all systems. One hard key shall be provided for each PTE. The device shall be designed such that duplicate units may not be unofficially obtained. The device shall be programmable by the Authority to limit its use (e.g., contains a time limit, only works with a specific PTE, etc.)

4. Batteries

a. Rechargeable batteries shall be sized to retain data for at least six (6) months without charging and shall be located such that leakage cannot damage any control system components. Battery life shall be no less than five years, regardless of type. The system shall annunciate the need for battery replacement such that the battery continues to perform its function until it can be replaced at the next periodic maintenance. Batteries shall not be connected by soldering. Non-rechargeable batteries shall be replaced within six (6) months prior to locomotive acceptance. Upon detection of the loss of input power to non-battery backed systems, the processor system shall store all necessary RAM control data to non-volatile memory. The Contractor shall provide a list of all components that include a battery.

5. Expansion Capacity

a. The hardware shall be designed to allow program expansion without hardware modification. The memory needs of the installed software shall not utilize more than 70 percent of the installed memory. This requirement applies individually to each type of memory installed, whether it is EPROM, EEPROM, Flash PROM, RAM, or other type. Peak processing time demands shall not be greater than 50 percent of the available processor time, except as indicated below. The Contractor may petition for relief from the 50 percent requirement, based on product maturity and the lack of potential for expansion or modification. In no case may more than 75 percent of the peak processor time be utilized, and generally, more margin shall be required. The hardware shall include spare input and output channels of each type used within the system, except for major output drivers, the quantity of which is fixed by the overall system design (e.g., traction motor semi-conductors and sign character drivers). In

addition, the architecture and assembly construction shall allow for the installation of additional I/O hardware. Simple singular functions performed by dedicated embedded processors may utilize up to 75 percent of the available processor time and do not have to provide spare I/O capability.

G. Deliverables and Schedule for Newly Developed Software

1. All documents submitted shall utilize revision bars in the margin and/or underline/strike through to highlight changes from one revision to the next. A change history shall be included in each document describing each change and giving the reason for the change.

2. The correspondence between design reviews and software submittals shall be as shown below. Issues with documents must be resolved and documents approved to close each design phase.

Figure 21-10: Software Submittal Requirements

Review Type	Software Related Documentation
Conceptual Design	General Software Configuration Management Plan (SCMP) for Contractor.
	Software Quality Assurance Plan (SQAP) for Contractor.
	Software Project Management Plan (SPMP) for Contractor
	Contractor Preliminary Overall System Functional Description (SFD)
	CMMI Reports, Improvement Plans, Interim Plans, and Monthly Progress Reports as required by the Technical Specification
Preliminary Design Review	System Functional Description (SFD) for each System
	Updated Overall System Functional Description (SFD) and Interface Control Documents (ICDs) for Contractor
	Software Quality Assurance Plans (SQAP) for Suppliers
	Software Project Management Plan (SPMP) for Suppliers
	Preliminary Software Configuration Management Plan (SCMP) for Contractor and Suppliers
	Preliminary Software Requirements Specification (SRSs) and ICDs
	Preliminary Software Test Plans (STPs)
	Preliminary Software Design Descriptions (SDDs) and Preliminary Database Design Descriptions (DBDDs) if needed at the Architecture Design level.
	Preliminary Software Verification and Validation Plan (SVVP) for Contractor and Suppliers
	Preliminary Software Requirements Traceability Matrix (SRTM) for each system
In-Process Design Review	Updated individual System Functional Descriptions (SFD)
	Overall System Functional Description (SFD) and Interface Control Documents (ICDs) for Contactor

Review Type	Software Related Documentation
	Software Requirements Specifications (SRSs) and ICDs
	Software Test Plans (STP) and Software Test Procedures (STPr)
	Software Design Descriptions (SDDs) – Architecture Design and Detailed Design and Database Design Descriptions (DBDDs) if needed
	Software Verification and Validation Plan (SVVP) for Contractor and Suppliers
	Software Requirements Traceability Matrix (SRTM) for each system
	Revisions to other documents for changes or updates
Final Design Review	Updated Systems Functional Descriptions (SFD)
	Updated Contractor Overall System Functional Description (SFD) and Interface Control Documents (ICDs)
	Updated Software Requirements Specifications (SRSs)
	Updated Software Test Plans (STPs) and Software Test Procedures (STPr)
	Software Design Descriptions (SDDs) – Architecture Design and Detailed Design and Database Design Descriptions (DBDDs) if needed
	Source Code Files
	Updated Software Configuration Management Plan (SCMP) for Contractor and Suppliers
	Updated Software Verification and Validation Plan (SVVP) for Contractor and Suppliers
	Software Requirements Traceability Matrix (SRTM) for each system
	Revisions to other documents for changes or updates

3. After original approval, changes to the software shall be formally submitted for approval prior to implementation of the changes in the source code. New versions of software must be accompanied by revised, reviewed and released software documentation, as well as SVVRs.

H. Configuration Control

1. The Contractor shall develop and maintain a Software Configuration Control Plan (SCCP) for tracking software changes relative to locomotives and PTEs. The Contractor shall include in the plan a data base management system capable of maintaining the history of all software and status changes making it possible to determine which versions currently resides in which equipment, on which locomotives, and also which versions were used in the past. The data base management system shall be capable of generating various reports showing the configuration of a typical vehicle system in terms of software history and status, and also a fleet configuration report capable of determining the exact software configuration of a particular operating train on a locomotive-by-locomotive basis. The Contractor shall make these reports available to the Authority.

2. The SCCP shall be submitted for approval.

3. The Contractor shall submit a final software configuration for each locomotive at the time of acceptance or conditional acceptance in an electronic format as approved

4. All software shall be identified by a name and a version number. The name shall identify the equipment into which the software is installed. Every change to software shall be reflected in an update to the version number.

I. Software Maintenance and Related Tools

1. The Contractor shall define and describe all items needed for software workstations including all of the software source files and software development tools used by the suppliers. The complement of equipment shall include all compilers, assemblers, linkers, in-circuit emulators, version control software, development kits, and other such tools that are used for software development. All such software and hardware tools shall then be provided and included in the escrowed material. Development tools and software which are identified must be the version as used by the suppliers. Specific instructions for compiling and linking the specific software shall be provided. The instructions shall include software modifications and tests of all non-Commercially available software (non-CA software) on this procurement.

2. The instructions and software documentation is to be demonstrated, and proven to create program files that then must match the programs stored within the system's equipment.

3. All associated manuals and software licenses shall be provided.

21.30 CLEANING

A. All debris from mechanical cleaning of vehicle components such as sandblast grit, and all debris resulting from building or overhauling operations, such as scrap, shavings, and insulation, shall be promptly removed from the vehicle or component.

B. All compounds and liquids used in cleaning and preparation operations shall be promptly removed, and flushed if required, from the vehicle or the component.

C. Every effort shall be made to remove all debris from the vehicle at regular intervals to prevent same from becoming lodged in inaccessible areas of the vehicle assembly.

1. Special care shall be taken to prevent drill cuttings and other materials from entering in areas of tubing, piping, or electrical wiring.

2. When drilling or other work has to be performed after installation or air brake equipment including piping, or electrical equipment including wiring, special precautions shall be taken to protect existing installation, in order to prevent future equipment problems.

3. Before release of the vehicle from the Contractor's plant, a final clean up and check of work shall be made.

4. Areas of particular concern area:

a. Electrical junction boxes, lockers, panels, and exposed terminal blocks where

retained metallic debris may cause future problems.

b. Oil, water, fuel and air tanks and piping from which debris could be drawn into valves, pumps, or other equipment.

PART 22.00 – QUALITY ASSURANCE

22.01 CONTRACTOR PROGRAM

A. Definition and Objective

1. The Quality Assurance Program is the achievement of consistence and uniformity of work performed by Contractor, Subcontractors, and Suppliers throughout implementation and adherence to documents described in the Quality Assurance Plan.

22.02 CONTRACTOR PLAN

A. The Contractor shall implement this plan into their Quality Management System Program and those of their Subcontractors and Suppliers as applicable. The Quality Management System shall be compliant with the current ISO 9001:2015 Standards.

1. The Contractor shall be responsible for insuring that their Subcontractors and Suppliers Quality Assurance and Quality Control systems are compliant with the Authority's specification and project contractual requirements.

2. The Authority shall have the right to audit and verify compliance of these quality systems throughout the Contract at Contractor, Subcontractor, and Supplier facilities.

B. Definition and Objective

1. The Project Quality Assurance Plan shall consist of the documented procedures, policies, plans, and organization activities of the Contractor, Subcontractor, Manufacturers, and Suppliers, which shall assure that all work, materials, test, and documentation conforms to the Authority's specification and project contractual requirements.

2. Within thirty (30) days after award of the Contract, the Contractor shall submit to the Authority for acceptance, a finalized, detailed, written Project Quality Assurance Plan consisting of, but not limited to the requirements outlined in these Specifications.

C. Contractor's Organization Chart

1. Contractor's organization chart shall be submitted in their technical proposal and shall show the lines of authority and responsibility for quality assurance and its relationship with other functions.

a. Titles and names of key personnel shall be shown.

22.03 CONTRACTOR CONTROLS

A. Documentation / Design Control

1. The Contractor shall have an established procedure for the control of drawings, change orders and other project-related documentations, to assure that contractually specified requirements are correctly and accurately translated into the drawings and specifications that are in use for existing procurement, fabrication, manufacturing, or testing.

B. Calibration Controls

1. The Contractor shall control all gauge, measuring, and test equipment, and assure that it is maintained in serviceable condition and accurate calibration. The calibration function shall meet the requirements of ISO 17025 and A2LA or approved MBTA equivalent.

2. Calibration standards shall be traceable to the National Institute of Standards and Technology (NIST).

3. Calibration history and frequency records shall be maintained and available.

4. Calibration dates and due dates shall be displayed on the equipment.

C. Manufacturing / Production

1. The Contractor shall have manufacturing and production work instruction documentation and established supporting procedures for work involvement throughout the course of the Contract.

2. These Work Instructions and shall include as a minimum, but not limited to, the following:

   a. Electrical components handling, installation, and test.

   b. Wiring, routing, bundling, solder, and terminations.

   c. Mechanical applications, torque limits, and fastener requirements.

   d. Assembly, installation, and adjustment instructions.

   e. Detailed instructions for verification and validation of completed work.

3. The Contractor shall control all work instructions, procedures, and changes thereto to assure that manufacturing, installation and testing processes are performed in accordance with the Contract or industry specifications, whichever is more restrictive.

D. Special Processes / Procedures

1. The Contractor shall have instructions, guidelines, documents or the established industry practices for use, in place for the performance of special processes or procedures.

2. These shall include as a minimum, but not be limited to the following:

   a. Magnetic Particle testing/inspection

   b. Dye Penetrant testing/inspection

   c. Radiographic testing/inspection

3. Personnel performing special processes shall be approved in accordance with applicable industry codes and standards.

E. Purchased Material

1. The Contractor shall establish procurement and performance specifications for use by Contractors, Subcontractor, Manufacturer, and Suppliers to assure compliance with the project quality requirements and this Specification.

2. The Contractor shall assure the Authority that all incoming material is specification compliant in proper condition.

    a. Items shall be identified by the applicable drawing, specification, or other document.

3. All material certifications and test reports used as the basis for accepting materials used for major components, shall be reviewed for compliance with all specifications and contractual requirements. This documentation shall be retained by the Contractor and incorporated into the Locomotive History Book(s).

    a. To simplify documentation, such tests which apply to materials affecting all units shall be reported in a single Appendix book which shall be provided in addition to the individual History Books.

4. The Contractor shall control all materials during storage and handling to prevent damage or deterioration.

    a. This control shall include identification of customer supplied materials (if any), shelf life items, and environmental controls.

    b. Contractor shall identify all shelf-life items and submit to the Authority for review and approval, a procedure documenting how it will be ensure that these items are not used past their shelf life.

5. The Contractor shall control materials, parts, components, and equipment that do not conform to specification to prevent their use in the finished product.

6. The control shall include identification, documentation, segregation, and dispositions of non-conforming materials.

7. The Contractor shall assure that the disapproved non-conforming material is controlled and dispositioned in a manner that will prevent its use on this Contract.

F. Subcontractor Controls

1. The Contractor shall survey, audit, and review Subcontractors', Manufacturers', and Suppliers' facilities to assure adequate capabilities to perform sub-contracted efforts in compliance with the Contractor's Project Quality Assurance Plan.

    a. Reports of these surveys, audits and/or reviews shall be provided to the Authority.

2. Subcontractors, Manufacturers, and Suppliers of electrical or mechanical systems of sub-systems, materials, or components, shall be required to demonstrate compliance with the Contractor's Project Quality Plan requirements, as applicable to the task.

3. The Contractor shall document the established requirements for Subcontractors,

Manufacturers, and Suppliers as applicable to Authority's specified contractual requirements.

G. Flow Chart

1. The Contractor shall control all manufacturing and production sequences through the use of a controlled Manufacturing Plan.

2. This plan shall be depicted as a product work flow block diagram showing each significant operation and the related controlled in-process or hold points for inspections, examinations, and tests.

3. This plan shall be compatible with an established Quality Control Inspection Plan.

4. All applicable documentation shall be referenced and/or noted in the plan.

22.04 CONTRACTOR INSPECTION PLAN

A. The Contractor shall prepare a Quality Control Inspection Plan showing major manufacturing and inspection milestones.

B. The Inspection Plan shall be used by the Authority to identify inspection, in-process witness, and hold points, to be observed by the Authority and the Contractor.

C. The Contractor shall assure that all processing, fabricating, and other production operations shall be accomplished under an in-process inspection Production Control System.

D. The Contractor shall prepare a test plan identifying each test required by the Contract and the point in time, or manufacturing sequence, at which it will be performed.

E. Each test shall be performed in compliance with a written test procedure prepared by the Contractor and approved by the Authority.

F. The test procedures shall include acceptance criteria defined by industry codes and standards or by this Specification, whichever is more restrictive.

G. The Contractor's Inspection Plan shall provide surveillance to assure that handling, storing, preserving, marking, and packaging of items during the production process is performed in accordance with Authority-approved procedures.

H. These records shall include results of examinations, inspections, tests, process controls, and all other quality control requirements of the Contract.

I. These records shall be maintained complete and in an orderly and easily accessible arrangement.

J. These records shall be available to the Authority at all times during the Contract.

K. At the end the Contract, all records which are required by the FRA and other records which are necessary for maintenance and operation of the locomotives shall become the property of the Authority.

L. The Contractor shall eliminate system conditions adversely affecting product quality, through effective program reviews and documented procedures that require evidence of the corrective actions taken, to preclude the recurrence of the identified deficiencies.

M. The Contractor's Quality Control Inspection Plan shall provide for inspection of items prior to their delivery under this Contract.

N. The inspection of items shall include documented verification of physical, visual, and complete documents in compliance to the Contract.

22.05 AUTHORITY PARTICIPATION

A. The Authority shall retain the right to witness or waive participation in all inspection activities from First Article Inspection through release for shipments at the Contractor’s, Subcontractors, Manufacturers, and Suppliers facilities.

B. The Authority shall retain the right to reject items found in non-compliance to the Contract specifications, industry practices, procedures, and documentation as applicable to

Contractor's, Subcontractors, Manufacturers, and Suppliers during the course of the Contract.

C. If the Authority elects to examine work partly or fully complete by a Manufacturer or the Contractor, such examinations shall be conducted by mutual agreement between the Authority and the Contractor so as not to impede the Contractor's production schedules.

1. Any special tests required by the Authority shall be performed by the Contractor using available Contractor appliances. The Authority's representative will verify the procedures and results.

D. Non-compliance workmanship or materials which are disclosed shall be corrected promptly.

22.06 LIFECYCLE MAINTENANCE / SERIAL NUMBERS

A. Contractor shall also be responsible for completing an Authority-provided spreadsheet containing all serial numbers of applicable components by locomotive road number. (see sample in **Appendix G**, electronic version will be provided to the successful bidder)

B. All serial numbers shall be recorded in an Authority-provided Excel spreadsheet, depicted in **Appendix G**, by locomotive road number, for all applicable components.

1. Multiple components per vehicle shall each be given an Authority-approved designation by position or otherwise.

2. "Original" Serial numbers shall be recorded on the provided spreadsheet for all applicable components as removed from vehicles during dismantling, or received separately from the Authority.

3. "Current" Serial numbers shall be recorded on the provided spreadsheet for all applicable components as applied to vehicles during reassembly, or shipped separately to the Authority.

C. Spreadsheets shall utilize Microsoft Excel, version to be as submitted by the Engineer.

D. Information on spreadsheets shall be updated monthly, with electronic copies supplied to the Engineer.

E. Information recorded on the reassembly spreadsheet shall be used as input to Part 24.01D – Vehicle History Book.

22.07 CAPITAL AND MAINTENANCE SPARES LIST

A. Contractor shall be responsible for providing a list of recommended parts and quantities for the general maintenance of the locomotives for service time of 10 years.

PART 23.00 – DRAWINGS AND SPECIFICATIONS

23.01 SHOP DRAWINGS AND SPECIFICATIONS

A. Individual drawings shall be prepared for each part unique to this Contract designed and / or manufactured by or for the Contractor.

B. The Authority will respect proprietary data within legal constraints and consistent with Part C7.9.4 of the Contract.

C. Assembly, sub-assembly and arrangement drawings shall include a complete Bill of Materials and Parts List on the field of the drawing describing all items, including the Sub-contractor's parts, and all equipment and specialty details which form part of the assembly.

D. All the drawings supplied by the Contractor in accordance with this Specification shall be so delineated that the wiring, piping, or mechanical interference between components shall be readily and clearly identifiable.

E. The Contractor shall submit all design layouts, assembly, and subassembly drawings of safety related features for review by the Contractor's Safety Engineer prior to their release for production to assure the safety of crew and maintenance personnel.

F. The Contractor shall maintain, and update as required, a log listing all drawings by number, revision, and title and showing dates of preparation, submission, and preliminary and final acceptance, and shall submit revised copies of same to the Engineer and Consultant at monthly intervals.

   1. Log shall be in spreadsheet format using Microsoft Excel, software version to be approved by the Engineer.

G. The Contractor shall submit to the Engineer and to the Consulting Engineer, in accordance with the schedule, Part C7.12.2, the following design and engineering drawings including but not limited to the following:

   1. General Arrangement Drawing

   2. Static Clearance Diagram

   3. Wiring Schematic

   4. Air System Schematic

   5. Styling and Painting Drawing

   6. Head End Power Equipment and Installation Drawings

   7. Other general drawings required for the understanding, operation, and maintenance of the locomotives.

   8. Drawings of all parts modified or replaced with different type or model through the overhaul program.

9. Master drawing list, updated on a monthly basis.

    a. Drawing list s shall be in spreadsheet format using Microsoft Excel, software version to be approved by the Engineer

10. The Authority will furnish the Contractor with prints of original drawings where possible.

H. The Contractor shall submit to the Engineer for review and approval, individual "Scheduled Maintenance Tables" for all major components, narrowed down to the lowest replaceable unit (LRU) component in the RMM and HMM documents.

1. These tables shall list the following columns as a minimum:

    a. Name of the procedure

    b. Major component/LRU

    c. Section of document where procedure is detailed/explained

    d. Frequency at which procedure is completed (i.e. 92-day, 184-day, 1-year, 2-year, etc.)

2. As these "Scheduled Maintenance Tables" shall facilitate the Authority in Lifecycle Maintenance activities, format and template shall be reviewed and approved by the Engineer.

I. Drawing Format

1. Contractor's standard drawings (drawings not prepared specifically for this Contract) shall be furnished with the Contractor's title block, shown in in Figure G200, and the Authority's Where Applied block as shown in Figure G205, in a convenient location in or near the upper right corner of drawings.

2. Format for drawings prepared specifically for this Contract shall be submitted to the Engineer for review and acceptance.

J. The Authority may exercise its right of First Article Acceptance as further review to confirm the validity of the Contractor's design and shop drawings.

K. The following procedure shall govern drawings submitted for review by the Engineer:

1. Draft Drawings shall be submitted electronically, in PDF format.

2. Three (3) copies of all catalog cuts, instruction books, renewal parts data lists, tabulations and the like not adaptable for the furnishing of reproducible, shall be supplied.

3. Final Drawings shall be submitted electronically, in CAD and PDF format.

4. The Engineer shall make every effort to expedite review of drawings to protect the Contractor's required lead time, and to protect delivery schedule.

L. **Review Procedure:**

1. Contractor submits drawings for review.

2. Engineer shall respond as rapidly as practical (thirty (30) working days average time from receipt) to the Contractor that drawings are in one of the following categories:

   a. Conforms

   b. Conforms as Noted

   c. Revise as Noted and Resubmit

   d. Rejected - Resubmit

   e. Review Not Required

3. Duplicate copies of drawings designated in any of the categories above shall be signed by the Engineer and Consulting Engineer, in a rubber stamped block to be applied by the Authority, with one copy being returned to the Contractor.

4. Drawings designated as “Conforms as Noted”, “Revise as Noted and Resubmit”, or “Rejected – Resubmit” shall be promptly (fifteen (15) working days average time from receipt) revised and resubmitted by the Contractor.

M. Review of Drawings Prior to Commencement of Overhaul Work

1. Overhaul work in the form of modification or reassembly on the various areas of the vehicle shall not commence until drawing(s) delineating the work to be performed on the particular area of the locomotive have been submitted to the Engineer and have been designated "Conforms" or "Conforms as Noted".

2. Contractor shall submit drawings for review in the order in which he intends to undertake work in the vehicle.

3. It is not the intent of the Authority to require that all drawings be submitted for review before any work can commence, however, the Contractor should submit drawings showing physically related areas of the vehicle as simultaneously as possible.

N. Review by the Engineer of the Contractor's drawings and data shall be for general detail and arrangement only, and shall not relieve the Contractor or Subcontractor of any responsibility for:

1. Full compliance and conformity of its drawings and data to the contract documents, requirements and Specification.

2. Correctness of dimensions, clearances, and material quantities.

3. Proper design of details.

4. Proper fabrication and construction techniques.

5. Proper coordination with Subcontractors.

6. Providing all devices required for safe and satisfactory overhaul and operation of the locomotives for the minimum Service Life defined in these Technical Specifications.

O. Contractor shall submit two (2) draft copies of the Contractor's Specification for preliminary acceptance with the design and engineering drawings.

1. It shall generally follow the format of the Authority's specification, listing all design criteria and parameters; the manufacture and model number of all major equipment; and the inspection and test procedures.

2. Provisions shall be made for listing all Change Orders and approved deviations from the procurement specification.

23.02 SCHEMATICS

A. The Contractor shall prepare and submit, for acceptance by the Authority, a totally integrated schematic diagram package relating all electrical systems and including all components and all wiring on the locomotive.

1. The schematic diagram shall be one which can be readily followed by anyone with basic electrical knowledge.

2. Both an alphabetic tabulation and pictorial locator of all electrical components and devices and the physical location of these components shall be included with the integrated schematics. This tabulation should also identify the circuits where components are used, and the location of each circuit in the schematic package.

3. Integrated schematic shall be drawn, in general, in the style of those produced by MPI for the Authority’s 1050/1030 Locomotives, samples of which may be inspected at the Authority's Railroad Operations office. The Draft Schematic format is to be submitted to the Engineer for review and acceptance.

4. In addition to electrical schematics, the integrated schematic package shall contain pneumatic and water schematics including, at a minimum:

a. Compressed Air System Schematic, including Friction Brake.

b. Locomotive Fuel System Schematic

c. Cooling Water System Schematic

d. Layover Circulation System Schematic

5. The schematics shall be accompanied by a complete Wire Running List. This list shall be provided in an electronic database format (with database software and license provided). The database shall be arranged in logical fields that will allow various sorts of the information (such as by equipment, wire number, conduit, etc.). Both hardcopy and electronic media file shall be provided.

6. The Wire Running List shall include for each wire as a minimum:

a. Origin equipment

b. Destination equipment

c. Wire size and type

d. Conduits through which the wire runs

e. Wire number

7. Complete wiring diagrams shall also be provided for all locomotive wiring. These diagrams shall be arranged logically and all text shall be clearly legible. Diagrams shall identify all conduits and raceways in which wires are run, identify all wires in each conduit/raceway, and shall clearly denote all connections at terminal blocks and connectors.

8. The schematics shall be provided both as full-size drawings and an 11" by 17" package to be used for troubleshooting. All schematics shall be prepared so that all text and other items on the drawings are clearly legible on the 11" by 17" sheets.

   a. The intent of the 11 x 17 inch format is that it shall be the same schematics as submitted as full size engineering drawings. It is not intended that the full size drawings are to be re-drawn in small scale, only that the larger drawings can be reproduced and legible on a smaller sheet of paper.

9. Samples of the schematic, electrical component/device table, wiring diagram, and wire run list shall be submitted to the Engineer for review and acceptance before manufacturing begins. Hand-drawn drawings shall not be permitted.

10. In addition to electrical schematics, the Integrated Schematic shall also provide physical schematic of electrical system.

11. The Integrated Schematics shall include all electronic and electrical components on the locomotive. Any minor subsystem components on PC boards or housed in "black boxes" shall also be included in the Record Drawings Schematic Package, and for the Integrated Schematic Package, shall be treated as black boxes, showing the box. Microprocessors will show list of outputs.

12. The Integrated Schematic Package shall be comprised of two parts.

    a. Volume I will include Index, Introduction, abbreviations, device list, symbol description followed by a set of electrical, pneumatic and water schematics.

    b. Volume II will include Index, Introduction, abbreviations, device list, symbol description followed by a set of electrical wiring diagrams and the wire running list.

13. The Draft Integrated Schematic shall be submitted before the delivery of the first locomotive.

14. An Interim Integrated Schematic shall be submitted for review with the delivery of the final locomotive. A Final Integrated Schematic shall be submitted as a Record Drawing. The Packages shall be stamped – DRAFT, INTERIM and FINAL, as appropriate.

23.03 CLEARANCE DIAGRAM

A. The Contractor shall accurately measure the units after rehabilitation and shall prepare an official MBTA clearance diagram for review and acceptance by the Engineer, similar to that shown in Figure A7.

B. The diagram shall be in the format of diagrams provided for the Authority's 1115-1139 series locomotives.

1. Drawing size shall be 22 by 34 inches.

2. The diagram shall show detailed half cross section.

3. The diagram shall show detailed side elevation.

4. Vertical dimensions shall reflect dry locomotive with new wheels and springs.

C. The diagram shall be prepared and corrected prior to shipment of the seventh rehabilitated vehicle to the Authority.

1. The diagram shall be corrected as directed by the Engineer.

2. The Authority requires Mylar copies signed by the Contractor's and the Authority's Engineers.

23.04 FINAL RECORD DRAWINGS AND SPECIFICATIONS

A. The following drawings and Contractor Specification shall be submitted for final record, after review by the Engineer, within thirty (30) days after Conditional Acceptance of the last vehicle:

1. Two (2) electronic copies of all final Contractor and Vendor drawings applied to the vehicles shall be provided in CAD and PDF format, as approved by the Engineer. These shall be provided on a CD/DVD or other suitable media, as approved by the Engineer.

a. Drawings shall comply with Figures G200 and G205 (see **Appendix F**) except where other details have been expressly accepted by the Engineer.

b. Parts Lists (Bills of Materials)

i. All drawings shall include parts lists with a numbering system for easy identification on the drawing.

ii. Parts list shall indicate piece part and assembly weights.

iii. Parts list shall include US equivalent materials.

iv. Parts lists shall be carried on the drawings, or on attached sheets of the same size which shall bear the same drawing number with an "/L1" suffix.

2. Four (4) copies of all catalog cuts, instruction books, renewal parts data (full detail, plus recommended list), lists, tabulations and the like, not adaptable for the furnishing of reproducible.

3. Four (4) copies of Contractor's Specification.

B. As-Built Drawings and Contractor's Specification shall have all engineering, manufacturing, and installation changes incorporated.

C. The Contractor shall furnish electronic files to the Authority and to the Consultant, at any time requested to do so prior to the delivery of the reproducible drawings, prints of each working drawing for the purpose of maintaining and servicing the vehicles.

D. The Contractor's attention is directed to Part **24.00** for details regarding the requirements for Operating Instruction Books, Maintenance Instruction Books, Renewal Parts Manuals, and Vehicle History Books.

23.05 PROJECT PHOTOGRAPHS

A. The Contractor shall take photographs showing the progress of the vehicles during overhaul.

1. Each photograph shall show a different view of the work and shall be made at the time and from vantage points as may be designated by the Engineer.

2. Additional photographs shall also be taken of major components, such as the frame, prime mover, head end power set, electrical cabinets, control stand, etc. during the assembly of the vehicle.

3. The approximate number of photographs to be taken during construction shall be fifty (50), at the discretion of the Engineer.

B. The Contractor shall furnish two (2) prints and two (2) electronic files of all photos in an editable format of each of the above photographs.

1. The prints shall have a gloss finish on durable stock suitable for the purpose, and shall be eight (8) inches by ten (10) inches (203 mm x 254 mm) in size, exclusive of a one (1) inch (25mm) binding margin.

2. Each print shall have permanently written on its back an identification number and legible description including the vehicle number, date taken, descriptive data, and the name of the Authority and the Contractor.

3. The prints shall be accompanied by the digital file transmitted in an electronic format.

a. Photographs, which in the judgment of the Engineer, produce unsatisfactory prints, slides, or negatives, shall be retaken by the Contractor at his own expense.

C. During the hours which the production facility is open and operating, the Authority's authorized representatives shall have the right to take additional photographs of the work with the Authority's equipment and at the Authority's expense.

D. All costs for the project photographs shall be included within the Contract price submitted.

23.06 DIMENSIONING

A. All measurements shall be in English dimensions; and the dimensions shall be expressed in

inches and fractions of an inch for less than one foot; feet, inches, and fractions of an inch for dimensions greater than a foot; or in decimal inches.

1. Metric dimensions may be included on drawings shown parenthetically either following or under the English dimensions.

2. Metric dimensions smaller than one (1) meter shall be shown in millimeters, and the dimensions one (1) meter and larger shall be shown in meters and decimal meters.

23.07 STATIONING

A. Numerical station dimensions and lines shall be used on all assembly drawings, and as frequently as possible on detail drawings, to locate the individual items in the overall configuration.

B. Stations shall be shown in three planes:

1. Longitudinally, commencing with the pulling face of coupler (P.F.C.) at the No. 1 end of the vehicle.

2. Transversely, commencing with the longitudinal center line of the vehicle and increasing left and right.

3. Vertically, commencing with the tops of the running rails.

4. Station figures shall be enclosed in circles.

a. Transverse dimensions shall have the letters "L" or "R" shown below the figures.

b. Vertical dimensions shall have the letters "ATR" (above top of rail) shown below the figures.

PART 24.00 – MANUALS AND TRAINING

24.01 INSTRUCTION BOOKS/MANUALS/VEHICLE HISTORY BOOKS

A. Operating Instruction Books

1. The Contractor shall prepare all required Operating Instruction Books.

2. The Contractor shall provide the Authority with a draft manual no later than thirty (30) days in advance of delivery of the first vehicle.

3. The size of the books shall be 9.25 in. x 4.25 in. (235 mm x 108 mm), with durable cover stock, and bound in a manner acceptable to the Engineer.

B. Maintenance Instruction Books

1. General:

a. Contractor shall be responsible for updating the Running Maintenance Manuals (RMM) and Heavy Maintenance Manuals (HMM) for each class of locomotives overhauled.

i. Contractor will be provided with a hardcopy of the most recent manuals.

ii. Revisions shall include updates completed as part of the overhaul as well as any updated EMD documentation.

2. Format:

a. Maintenance Instruction Books shall be 8.5 x 11 inches (216 mm x 279 mm) in size; of the 3-hole, loose-leaf type; be completely indexed; and be bound in hard cover binders.

b. All covers shall be approximately 1/16 inches thick, resistant to oil, moisture and wear to a high degree, commensurate with their intended uses and subject to Engineer approval.

c. Diagrams and illustrations shall be line drawings and shall not be loose or in pockets.

d. All material shall be clearly reproducible by dry copying machines, which precludes the use of halftone illustrations or photographs.

3. Contents:

a. The RMMs and HMMs shall be updated to address all changes related to the overhaul of the locomotives. This includes new equipment, new maintenance practices and any other relevant changes required to effectively and efficiently maintain the overhauled locomotives in a state of good repair.

b. Safety Inputs into text shall include Notes, Cautions and Warnings. Content and Font shall be similar to that shown in the body of the examples shown below:

Note: This is the format for a level 1 note. Notes are used to call the reader's attention to important information that might be lost within a block of text.

Caution: This is the format for a level 1 caution note. Caution notes are used to alert the reader to a potential hazard to equipment, software, or data.

Warning: This is the format for a level 1 warning note. Warning notes alert the reader to a potential personnel hazard.

c. The Maintenance Instruction Books shall include vendor's instruction books for specialties, including, but not limited to the following:

i. Air Brake

ii. Cab Signal and Speed Control

iii. Event Recorder and Indicator

iv. Alertness System

v. Air Conditioning

vi. Head-End Power Unit

4. Draft Copies:

a. No later than thirty (30) days in advance of delivery of the first vehicle, contractor shall submit for review by the Authority triplicate copies of:

i. A complete sample draft of all maintenance instructions specifically prepared for this Contract that are to be incorporated into the Maintenance Instruction Books

ii. All cuts and diagrams.

5. Final Copies:

a. The Contractor shall provide twenty (20) hardcopies and one (1) electronic file of the Maintenance Instruction Books for all equipment and parts no later than sixty (60) days after delivery of the first locomotive.

i. Contractor shall supply updated coversheet indicating its applicability to the overhauled locomotive type, and road numbers of the locomotives addressed.

ii. These copies shall incorporate all revisions required by the Authority and mutually agreed to by the Contractor.

iii. Contractor shall be responsible for updating the Maintenance Books with any modifications from the warranty period.

b. Contractor shall also supply the completed manuals on CD-ROM in Adobe PDF format.

C. Renewal Parts Manuals

1. General:

a. The Contractor shall provide twenty (20) hard copy and one (1) electronic file Renewal Parts Manuals with delivery of the first vehicle.

b. The Contractor shall subsequently provide replacement pages and / or hard-bound copy, or other format mutually agreed upon, as necessary so that these manuals reflect any changes from the original parts listing.

2. Format:

a. These manuals shall be 8.5 in. x 11 in. (216 mm x 279 mm) in size of the 3-ring, loose-leaf type and be completely indexed

i. Renewal Parts Manual for such items as engines, alternators, and traction motors that supplement the Renewal Parts Manuals may be 3-ring punched hard-bound copy in lieu of 3-ring loose-leaf type copy.

b. Contractor shall also supply the completed manuals on CD-ROM in Adobe PDF format.

D. Vehicle History Book

1. General:

a. The Contractor shall furnish to the Authority an updated Vehicle History Book for each vehicle.

2. Format:

a. Vehicle History Books shall be 8.5 in. x 11 in. (216 mm x 279 mm) loose-leaf type book.

b. Diagrams and illustrations shall be line drawings and shall not be loose or in pockets.

c. All material shall be clearly reproducible by dry copying machines, which precludes the use of halftone illustrations or photographs.

d. Contractor shall also supply the completed Vehicle History Books on CD in Adobe PDF format.

3. Contents:

a. Each Vehicle History Book shall record the following information:

i. Vehicle Number and Class.

ii. Serial numbers of all wheels, axles, motors and any other apparatus with serial numbers.

iii. Weight of vehicle, by truck, and total.

iv. Wheel and axle mounting records.

b. The Contractor shall confer with the Engineer as to the format of these records.

c. It shall be the responsibility of the Contractor to employ an acceptable system of configuration control in keeping individual History Books current.

4. Draft Vehicle History Book for each locomotive, incorporating serial record data, shall be submitted once the associated locomotive has left the overhaul facility.

5. Vehicle History Book for each unit shall be updated to match the vehicle's final configuration no later than thirty (30) days after conditional acceptance of that particular vehicle.

a. Each Final History Book shall include all updates to the Draft Vehicle History Book for the associated locomotive including, but not limited to, testing documents, FMIs, updated serial number list, software log, and any additional information that was changed or added after the locomotive's departure from the overhaul facility.

24.02 INSTRUCTION BOOK/MANUAL/VEHICLE HISTORY BOOK GUIDELINES

A. Preparation

1. All pages which are written pursuant to this contract shall be prepared using a computer based text preparation and editing system such that:

a. Revision of pages does not require retyping of material which is unchanged.

b. Changes relative to the version most recently submitted to the Engineer for review are highlighted by distinctive underlining, or by some distinctive indication in the margin.

c. Every page shall indicate the date of its print-out as well as its page number and the manual to which it belongs.

2. All document shall be submitted to the Authority for review of format and content prior to publication.

a. A complete dummy volume of each manual will be required.

3. With the delivery of the last locomotive the Contractor shall also provide the Authority with an electronic copy on a CD ROM in a format compatible with software used by the Authority.

a. If files cannot be written in a compatible format, the Contractor shall provide the appropriate software to the Authority to allow updates to be made by the Authority at a later date.

B. Binding and Printing

1. These instructions apply to the printing and binding of the following documents:

   a. Maintenance Instruction Manuals

   b. Renewal Parts Manual

   c. Vehicle History Books

2. Text and drawings shall be printed on 24 pound white stock, punched for American standard hole pattern.

   a. Section separators are to be heavy duty buff stock with punched edge reinforced with Mylar, and reinforced number tabs.

   b. Internal section separators where applicable, shall be heavy duty white stock with punched edge reinforced with Mylar, and reinforced label tabs marked "Vendor" or other designation as appropriate.

   c. Front and rear clear plastic separator pages shall be provided in each volume to separate printed pages from contact with covers.

   d. Heavy duty plastic page lifters shall be provided at front and rear of each volume.

   e. Layout of text and title pages and sample text pages and internal section separators shall be submitted for Authority approval, and shall follow the corresponding pages for manuals for the Authority's overhaul of the 700/1700 series coaches.

3. Binders shall be heavy weight white vinyl covered, with clear full size vinyl pockets on front cover and spine.

   a. Binders shall have heavy duty post or expanding post catalog type mechanism, Cardinal or equal.

   b. Insert sheets for front cover and spine shall be light pastel card stock with black printing, and shall have clear protective face sheet to prevent print transfer to vinyl face pocket.

   c. Layout of cover and spine inserts shall be submitted for approval, and shall follow the corresponding items for manuals for the Authority's overhauled 700/1700 series coaches.

4. Samples of all binders, and papers and other related materials listed above shall be submitted for review and acceptance by the Authority as part of the dummy volumes required by **Part 24.02A.2.a**.

C. Shipment of Manuals

1. All Maintenance Instruction Books, Renewal Parts Manuals, and Vehicle History Books shall be shipped separately to the Authority at the address designated by the Engineer.

24.03 MAINTENANCE EDUCATIONAL PROGRAM

A. General

1. The Contractor shall provide a comprehensive educational program for the Authority's personnel to permit satisfactory servicing and maintenance of the vehicle.

2. The program shall include both formal and informal instructions using such training aids as slides, motion pictures, manuals, diagrams, etc. as may be available.

3. All training documentation shall be provided to the Authority for review and approval no later than sixty (60) days prior to the start of training.

B. Intent

1. The Contractor shall provide training in a train the trainer format. This training should be geared towards individuals who have a basic knowledge of the F40 Locomotive. It is expected that adequate information will be provided to assist these individuals with developing a comprehensive curriculum enabling the trainer to train personnel with no knowledge of the vehicle.

2. Educational program for the Authority’s personnel to permit satisfactory servicing, maintenance, inspection, repair and troubleshooting F40 locomotive.

C. Program Content

1. The program shall include all information necessary for satisfactory servicing, maintenance, inspection, repair and troubleshooting of the F40 locomotive. In-depth instruction shall be provided for but not limited to the following subjects:

   a. Vehicle Overview

   b. Calendar day inspections for F40 for Machinist, Electrician and Carman

      i. Interior inspection

      ii. Exterior inspection

   c. Periodic inspections for Machinist, Electrician, Carman, Sheet Metal Worker and Boilermaker.

      i. 45 days, 92 days, 184 days, 1 year, etc...

   d. Maintenance and Repair

      i. Prime Mover Engine

      ii. Fuel System and Engine Starting

      iii. Lubricating Oil system

      iv. Cooling system

v. Central Air system

vi. Compressed Air System

vii. Electrical rotating Equipment (main generator, alternator, traction motor, auxiliary generator)

viii. HEP system

ix. Layover protection System

x. Wheel slips system

xi. Dynamic Brake

e. Troubleshooting

i. Battery

ii. Circuit breaker

iii. Crankcase pressure

iv. Current transformer

v. Dynamic brake module

vi. Fuse

vii. Load test

viii. Generator voltage

ix. Hot engine

x. Low oil pressure

xi. Sanding module

xii. Sensor module

xiii. Temperature switches

xiv. Voltage regulator

xv. Throttle response

xvi. Wheel overspeed

xvii. Any other topics deemed relevant through mutual agreement by the Contractor and Authority

f. Head End Power System

i. HEP system components

ii. HEP cabinet

iii. HEP panel

iv. HEP cooling system

v. HEP Engine Troubleshooting

vi. HEP Engine Maintenance and Repair

g. Cab Signal and Speed Control

h. Civil Speed Enforcement Equipment.

D. Subject Content

1. Classroom instruction shall include both the anatomy and function of the parts under discussion and the essentials of routine care including servicing schedules, adjustments, inspection and test frequency, troubleshooting, removal, and replacement.

2. The Train-the-Trainer shall include both classroom and hands on instruction using training aid such as slides, manuals, diagrams, etc.

3. Overhaul procedures shall not be included in the program.

E. Facilities

1. The formal classroom instruction will be conducted in a suitable classroom furnished by the Authority on its or its Operating Contractor's premises.

2. Informal field instruction may also be conducted on and around the locomotives at any of several maintenance facilities.

F. Authority Cooperation

1. The Authority will lend its fullest cooperation to the carrying out of the program, however, the times and duration of the instruction period and the number of personnel available to attend classes must necessarily be at the discretion of the Authority and / or its Contract Operator.

G. Student Availability

1. The following numbers are furnished as a guide to the magnitude of the effort required:

a. Number of personnel to be instructed: 40

b. Each class of students shall be made available for eight (8) hours per day for a minimum period of two (2) weeks.

c. Contractor shall provide training material for twelve (12) people in the first of each course. Electronic copies shall be provided to the Authority in PDF and PowerPoint in advance of each class.

24.04 SPECIAL TOOLS AND FIXTURES

A. Any special tools, jigs, fixtures, adapters (excluding a basic mechanics set of hand tools or portable volt meter) introduced into the maintenance requirements of these vehicles through the overhaul program shall be supplied to the Authority by the Contractor.

1. Two (2) sets shall be supplied, consistent with the maintenance needs of the vehicles.

2. "Special tools" is defined as non-commercially available tooling made specifically for these locomotives and/or its subsystems that are used for maintenance /repair of the vehicle, in accordance with the Contractor's practices.

3. Detailed drawings suitable for manufacturing of these special tools shall be provided.

4. All tools and equipment used for the repair/troubleshooting of the HVAC unit designed for R-407C shall be considered special tools. Two (2) complete sets shall be delivered with the first locomotive.

PART 25.00 –TEST EQUIPMENT

25.01 PORTABLE TEST EQUIPMENT (PTE)

A. General

1. The Contractor shall provide portable test equipment to allow maintenance personnel to troubleshoot, calibrate, or adjust all systems, subsystem and field adjustable components on the locomotive.

2. The PTE equipment may either be computer or hardware based or a combination of the both. If the PTE contains both hardware and software then it shall met both requirements listed below.

3. PTE's shall be delivered with the Pilot locomotive to allow the MBTA to verify functionality and use during testing.

B. Basic Operation

1. The function of each of the portable test devices shall be to produce all of the operating commands and other input signals necessary to fully exercise all functions and components of the particular system under test, and to measure or indicate all of the signals, responses and outputs produced by a system.

2. When used according to the instructions supplied by the Contractor, each portable test device shall enable the maintenance technician to fully check out and calibrate the system under test, and to locate and replace any removable component which has failed.

3. The portable test device shall not be used to calibrate high-current and high-voltage devices.

4. Response indicators and input signal generators shall be built into the portable test devices to the maximum extent possible, and shall have accuracy commensurate with alignment tolerances specified.

5. Indicators shall be digital LED type except where specifically approved to be otherwise.

6. Connection of external apparatus to the portable test devices shall not be required without the prior written approval of the Authority.

    a. In such cases, terminals shall be provided to allow connection of the required apparatus to the portable test device.

    b. Such apparatus shall be considered part of the portable test device and shall be supplied with it on a one-to-one basis.

7. This test and diagnostic equipment shall be delivered to the Authority for its use prior to any testing on any locomotives, including the prototype locomotives.

8. This test and diagnostic equipment shall be equal, as a minimum, to the equipment used by the Contractor and its suppliers.

9. The Contractor shall thoroughly instruct the Authority in the test and diagnostic equipment's use, including software and its programming, prior to arrival of the prototype locomotives.

10. The Authority reserves the right to use this equipment to check and test any vehicle functions as required during any phase of testing or operation.

11. Any changes or modifications made to the Contractor's or supplier's equipment shall, at the same time, be made to the Authority's equipment.

C. System Requirements

1. Portable test equipment shall be supplied for, but not limited to, the following locomotive systems:

   a. Propulsion, including microprocessor controls, engine controls, interlocks, master controller, and locomotive interfaces

   b. Dynamic brake, including blended brake

   c. Wheel Spin/Slide

   d. Auxiliary Power, three phase AC and battery DC

   e. Trainline Circuits

   f. Public Address System/Intercommunication System/Radio

   g. Friction Brake

   h. HVAC

   i. Cab Signal System

   j. Head End Power System

   k. Alerter System

   l. ACSES

2. Test sets shall include all cable connectors and associated equipment, to interface with the test points.

D. Computer Based PTE

1. The Contractor shall furnish six (6) Computer Based PTE units. These units shall be a the latest high-end ruggedized notebook computers at the time of FDR

2. Each unit shall be equipped with all the software, connectors and cabling necessary to interface with all processor based locomotive systems.

3. Unless otherwise approved by the Authority, the PTE shall utilize only a standard,

commercially-available HTML web browser software to control and display any PTE function when connected to the SDS or the CDS.

4. There shall be a common PTE connector for all systems on the locomotive. The use of adaptors is prohibited. The PTE connection shall use a USB, RJ45 (Ethernet) connector on the PTE side, and shall use a ruggedized connector on the vehicle interface side meeting the requirements of MIL-DTL-5015, Class D or equivalent. The use of DB9 connectors on the PTE side is prohibited. The use of DB9, USB, or RJ45 connectors on any vehicle equipment is prohibited. All PTE connectors shall be grouped in a single location in the locomotive cab in an arrangement accepted by the Engineer.

5. The PTE shall include software to allow analysis of all data downloaded from all the CDS or SDS

6. All PTE software shall adhere to the Microsoft Windows User Experience - Official Guidelines for User Interface - Developers and Designers (ISBN: 0735605661) and shall include a Windows™ format help file to provide context sensitive help to the user of the software.

7. The PTE units shall provide the Authority complete and expedient access and monitoring, to all data in the SDS and CDS; such as locomotive parameters (motor currents, acceleration and deceleration rates, brake pressure, logic control) on-board status, self test, and self diagnostics .

8. The intent is for the Authority, while on board the locomotive in revenue service operation, to monitor and record vehicle performance and capture it on electronic media and/or hard copy for later review. The output shall represent in both graphic (e.g. a strip chart recorder) and tabular form all information necessary to verify the safe and proper in-service operation of the vehicle.

9. The PTE shall include on-line troubleshooting guide to assist maintenance personnel in identifying the defective component. This on-line guide shall be in clear English and shall utilize trouble shooting trees or other step by step instructions to localize the fault.

10. The PTE shall be capable of reading data on the memory storage device without any external hardware.

25.02 MEMORY TRANSFER DEVICE (MTD)

A. The contractor shall provide hardware and software to allow download and upload of data or software etc. to any processor based systems.

B. To the maximum extent possible there shall be only one type of memory transfer device.

C. The contractor shall provide 25 (Twenty five) of each type of memory transfer devices used on the locomotive by each subsystem.

D. The MTD shall be either a compact flash device or USB memory flash drive as approved by the Authority.

E. The MTD shall be configurable via a file on the MTD to automatically perform data transfers without any user action. e.g. Download data for specific faults, date, time, etc. Upload

software etc.

F. The use of an incorrect or defective MTD shall not adversely affect the operation of any system.

G. The incorrect insertion of the MTD shall not damage the on board hardware.

H. Each system's MTD connection shall be easily field replaceable without soldering.

PART 26.00 – SAFETY

26.01 FAILURES

A. Any changes to the locomotive design and construction shall provide protection against failures, including software failures, which could cause an unsafe condition such that two or more sequential failures will be required for such condition to occur.

1. A single failure shall not result in an unsafe condition and shall energize an alarm.

2. Contractor shall notify the Authority of any identified unsafe conditions that are related to the original design.

26.02 TESTING DOCUMENTATION

A. In addition to all other testing documentation required by this specification, the Contractor shall provide four (4) copies of a Testing Summary Book to the Authority upon acceptance of the first or pilot locomotive.

B. The Testing Summary Book shall be delivered as three-ring binders, and shall include the following information:

1. Vehicle Level Qualification Test Plan, with Procedures.

2. Vehicle Level Qualification Test Results for the first or pilot locomotive.

3. Static Vehicle Acceptance Checklist results for the first or pilot locomotive.

4. Flame and Smoke Test Results and MSDS Documents

5. Copy of the Fire Safety Analysis, as required by Part 26.03.

26.03 FIRE SAFETY ANALYSIS

A. The Contractor shall perform a Fire Safety Analysis as described in 49CFR238.103.

B. A preliminary Fire Safety Analysis shall be presented to the Engineer no later than 60 days after Notice-to-Proceed. The presentation shall include explanations of all design decisions made with regard to fire safety, fire resistance, evacuation, ventilation, etc.

C. The preliminary Fire Safety Analysis must be reviewed and accepted by the Engineer before production on the vehicles begins.

D. Any requests for design changes or modifications throughout the design and production process, including field modification, must be accompanied by any resulting changes to the Fire Safety Analysis. Interim copies of the Fire Safety Analysis shall be submitted to the Engineer at each revision.

E. The final Fire Safety Analysis shall be presented to the Engineer 30 days after acceptance of the final locomotive.

F. The Contractor shall include in the maintenance manuals written procedures for the

inspection, testing and maintenance of fire safety systems and fire safety equipment, in compliance with 49CFR238.103(e).

26.04 SYSTEM SAFETY PROGRAM

A. The Contractor shall develop, implement, and maintain a comprehensive System Safety Program (SSP) conforming to the guidelines and requirements of 49CFR238 Subpart B, and of all applicable sections of MIL-STD-882, Rev. C. The Authority will use the implementation guidelines of Appendices A and B of MIL-STD-882 as the basis for determining acceptability of the Contractor's SSP.

1. Although superseded, the Contractor shall use MIL-STD-882, Rev. C.

B. The SSP shall identify all hazards related to the vehicle and impose design requirements and management controls which prevent mishaps by eliminating hazards or reducing risk to levels acceptable to the Authority. The SSP shall be developed in the earliest phases of the Contract and shall be continuously maintained throughout, as design and construction evolves.

C. Safety requirements defined in this Specification shall be incorporated into the SSP and the Contractor's designs.

D. Formats for reports, listings, analyses, and other required submittals shall be jointly determined between the Engineer and the Contractor.

E. The term MA appearing within MIL-STD-882 shall be interpreted as meaning the MBTA. All responsibilities imposed upon the MA by MIL-STD-882 shall be considered as completely satisfied by the contents of this Specification. The Contractor is solely responsible for the development of the SSP.

F. Hazards shall be resolved according to the precedence rules listed in Paragraph 4.4 in MIL-STD-882, with the restriction that hazards with Category I and II severity (as defined in MIL-STD-882) shall be resolved only by Methods 4.4a or 4.4b of that paragraph.

G. The general safety design requirements in A.4.3.3 of MIL-STD-882, and the guidelines listed below, shall be incorporated into the design of all vehicle systems affecting safety:

1. Only components with high reliability and which have been proven in conditions similar to the projected service shall be utilized.

2. All devices not guaranteed fail-safe shall be assumed capable of failing in permissive modes.

3. All electronic circuits and software shall be assumed capable of failing in permissive modes.

4. Systems shall be based on closed-circuit principles in which energized circuits result in permissive conditions, while interrupted or de-energized circuits result in restrictive conditions.

5. All vital circuits not wholly within the system apparatus enclosure shall be double-wire and double-break, with the exception of connections to non-vital circuits, which may be single-wire and single-break.

6. Any component or wire becoming grounded shall not cause a permissive condition. Safety circuits shall be kept free of any combination of grounds that will permit a flow of current equal to, or in excess of, 50% of the release value of any safety device in the circuit.

7. Circuit impedances, signal encoding, shielding, layout, and isolation shall be selected to minimize the effects of interference to the extent that safety is maintained under all conditions.

8. Commands that result in permissive conditions shall be propagated by no less than two independent signals, both of which must be present before the permissive condition can occur. The lack of either signal shall be interpreted as a restrictive command.

9. Systems controlled by variable level signals shall be arranged such that zero signal level results in the most restrictive condition. At least one enabling signal, however, independent from the variable control signal, shall be present before the control signal can modulate the system to a more permissive level.

10. Circuit breakers and fuses shall be guaranteed by the manufacturer to successfully interrupt rated currents. Circuit breakers and fuses shall be applied such that the maximum circuit fault currents cannot exceed the manufacturer's guaranteed operating ranges.

11. Systems that rely on structural integrity for safety shall have sufficient safety factors such that failures are not possible within the life of the vehicle under all possible conditions.

12. Devices subject to wear shall not wear to permissive states within a period less than three times the overhaul period under the worst-case combination of duty cycle, environment, and all other influences. Such devices shall be clearly indicated as SAFETY CRITICAL in the maintenance manuals.

13. Mechanical systems which apply force to achieve safe states shall not depend upon the application of fluid pressure or electrical energy, unless specifically accepted by the Authority.

14. All locks, catches, and similar devices affecting safety shall be either self-engaging without application of power, or, if engaged by application of power, shall remain fully and safely engaged in the absence of power.

15. All systems shall function safely under all combinations of supply voltages, fluid pressures, shock, vibration, dirt accumulation, and the intended service environment.

16. All safety-related systems, and devices within those systems, shall be clearly identified as SAFETY CRITICAL in all maintenance manuals, procedures, and training materials.

H. Failure Induced Hazards

1. The term "failure" includes both the initial device failure and all consequential device failures caused by the initial failure.

2. The term "device" includes any Component, Subsystem, or System, whether electrical or mechanical.

3. The terms "restrictive" and "permissive" relate to potential system responses, which result in either a more-safe or less-safe condition, respectively, such as: stop vs. proceed or the actuation of alarm vs. no actuation of alarm.

4. The Contractor shall employ high quality components, proven systems, redundancy, checking devices, and other techniques to ensure vehicle equipment and systems shall be designed and constructed to revert to safe modes under failure conditions

5. Vehicle systems whose failure could result in hazards of Category I or II severity (as defined in MIL-STD-882) shall conform to both of the following design principles:

    a. The failure of a single device shall not result in a permissive condition. For certain pneumatic devices, the acceptable permissive conditions created by device failures are as permitted by the Specifications in the relevant areas, and

    b. An undetected failure of any device shall not permit a subsequent device failure to result in a permissive condition.

6. All systems shall conform to the safety design principles by one or both of the following methods:

    a. The utilization of fail-safe devices, that is, devices with known, guaranteed-by-the-manufacturer failure modes, such as signal grade relays.

    b. Independent channels with independent checking of each. All channels shall indicate a permissive state in order that the controlled system achieve a permissive state. Failure in any channel shall not affect any other channel, or force the system into a permissive state. Lack of correspondence between channels shall be alarmed and shall force a restrictive state on the system. Checking equipment invariably requires devices conforming to this method.

7. Failures in equipment which result in an indication of danger, whether or not actual danger exists, shall be considered to have occurred in a safe manner. Conversely, a failure, which results in the lack of the ability to recognize an unsafe condition, when in fact an unsafe condition may exist, shall not be considered safe.

I. The Contractor’s System Safety Program shall include a software safety section that will apply to any embedded or external software or firmware which controls or monitors safety-critical functions. The requirements for software safety, as clarified in the following two paragraphs, which shall be in addition to all requirements of this specification, shall meet or exceed the requirements of 49CFR238.105, Software Safety Program, Paragraph (b) and CENELEC EN50128, designed to a safety integrity level 4.

    1. Software safety requirements shall treat software as an integral part of a hardware/software system. Functions accomplished through the use of software shall be considered safety critical unless an independent redundant hardware means is also provided to accomplish the same function.

    2. Features of the software safety program shall include a description of how the following shall be accomplished: definition, implementation and oversight of the software design and verification process, integrity of the documentation, software hazard analysis, software safety reviews, software hazard monitoring, reporting and tracking, and

software integration with hardware at each stage of the design and testing process for components, subsystems, systems, cars, locomotives, consists and trains incorporating software for safety-critical functions.

26.05 FIRE AND LIFE SAFETY

A. The Contractor shall comply with the requirements of 49CFR238.103 and 238.117.

B. All vehicle components, subsystems, and systems shall be designed for the prevention of fire; protection of the public, employees, and emergency response personnel from injury due to fire, smoke, explosion, or panic due to fire; and protection of system elements from damage by fire or explosion.

C. Equipment that is a potential fire hazard shall be appropriately isolated from the cab.

D. Vehicle construction shall be designed to prevent propagation of an underfloor fire to the vehicle interior.

E. Fire stops shall be provided at floor and roof penetrations.

F. Enclosures for control and other critical equipment shall be located to provide protection against environmental contamination and mechanical damage.

26.06 SAFETY UNDER NORMAL OPERATING CONDITIONS

A. The vehicle shall present a safe, hazard-free environment to operating and maintenance personnel to the every extent practical.

B. Operating personnel shall not be exposed to tripping hazards, sharp points and edges; any voltage of 50 volts or more, including between cars on adjacent tracks; toxic materials; or similar hazards.

C. Location, illumination levels, colors, graphics, and surface finishes shall be selected to maximize visibility of door thresholds, windscreens, controls, and other objects with which the passengers must interface.

D. Normal and emergency equipment and controls shall be clearly identified, and operating procedures shall be presented in both text and graphic formats.

E. In compliance with 49CFR238.117, all moving parts and high voltage equipment, electrical conductors and switches and pipes carrying hot fluids or gasses shall be appropriately equipped with interlocks or guards to minimize the risk of personal injury.

F. For the purpose of this requirement, voltages over 120 volts shall be considered high voltage.

G. All equipment enclosures containing hazardous materials, lethal or injurious voltages, or other risks shall be clearly labeled on both the outside and inside of the equipment enclosures.

26.07 HUMAN ERROR AND OTHER EXTERNAL INFLUENCES

A. The Contractor shall use MIL-STD-882 and MIL-STD-1472 as guides. All systems shall minimize unsafe conditions resulting from human error. No sequence of operations, or the

simultaneous activation of any controls, shall result in unsafe conditions. Where conflicting commands, such as simultaneous power and brake, are requested, the more restrictive shall result.

B. Maintenance of safety-related equipment shall be arranged such that the effects of errors are minimized. Methods such as limitation of adjustment ranges, unalterable software, non-interchangeable parts, and visible wear indicators shall be employed.

26.08 FAILURE MODE EFFECTS AND CRITICALITY ANALYSIS

A. The Contractor shall perform Failure Mode Effects and Criticality Analysis (FMECA) to identify weaknesses in system hardware and software design, and to analyze the modes and effects of failures. The FMECA shall provide input to system designs and to the safety analyses for theoretical circuit behavior, random component failures, electrical interference, systematic component failures, and software errors in software-based logic. FMECA shall be updated throughout vehicle design development.

B. Hazard Identification

1. The Contractor shall identify all failure-induced and normal operating (non-failure condition) hazards falling into severity Categories I, II, and III (as defined in MIL-STD-882). Hazards shall be compiled into lists and submitted to the Engineer for review and acceptance.

2. As required by MIL-STD-882, hazard lists shall be organized into a Preliminary Hazard List (PHL), Subsystem Hazard List (SSHL), and System Hazard List (SHL).

3. In addition to those hazards identified by the Contractor, the following hazards shall be included in the listings and shall be considered hazards of Category I or II severity:

a. Emergency brakes fail to apply when requested.

b. Service brakes fail to apply when requested.

c. No-motion detection system indicates no-motion when train is moving.

d. Excessive currents or overheated equipment cause fire hazard.

e. Primary Failure of Truck or Bolster Frame.

f. Primary Failure of Wheel/Axle Assembly.

g. Primary Failure of Suspension.

h. Primary Failure of carbody weldment or draft system.

C. Hazard Analyses

1. The Contractor shall perform hazard analyses on all hazards identified in the Hazard Lists developed in T26.08.B.2. Analyses shall demonstrate that the vehicle conforms to the requirements of this Specification and that all identified hazards are either eliminated, or reduced to levels of risk acceptable to the Authority.

2. Any requests for design changes or modifications throughout the design and production process, including field modification, must be accompanied by any resulting changes to the hazard analysis. Interim copies of the hazard analysis shall be submitted to the Engineer at each revision.

3. The analysis methods shall be selected by the Contractor as appropriate for the system under evaluation and the category of hazard severity. Hazards of Category I and II severity shall receive analyses sufficiently rigorous to demonstrate that the hazard cannot occur under any reasonable conditions. The Contractor shall be prepared to demonstrate, by test, the validity of any portion of all analyses of Category I or II severity hazards.

4. Standard failure and safety analysis methods, and published failure rates for components, shall be utilized wherever possible. All electrical circuit failure mode analyses shall include a sneak circuit analysis. All methods shall be submitted to the Engineer for review and acceptance.

5. Existing hazard analyses of subsystems may be submitted provided the analyzed subsystem is identical in all respects to that proposed, including the operating environment, and the analysis method is sufficiently rigorous. Analyses or tests required by other sections of this Specification, such as structural analyses, may also be submitted for consideration by the Authority where appropriate.

6. Analyses shall examine the vehicle as a single locomotive and as part of a consist, and shall include circuit faults within the trainline circuits.

7. Analyses shall identify all maintenance errors that could result in unsafe conditions, such as incorrect adjustment of sensors or limit switches.

8. Analyses shall include design errors that could produce unsafe conditions, such as improper breaker type or rating and temperature or environmental dependence on proper operation for use in checking designs.

Appendix A : Special Conditions Applicable To Individual Units

Unit	Special Conditions
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Appendix B : Generator Overhaul Specification

Appendix C : Traction Motor Overhaul Specification

Appendix D : Engine Overhaul Specification

Appendix E : HEP Genset Tier II Upgrade Specification (Option)

Appendix F : Figures

Appendix G : Serial Number Tracking Spreadsheet Sample